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Liquidity in Equity Markets

Yuping Huang

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Adam Smith Business School

University of Glasgow

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Abstract

This thesis aims to explore stock liquidity, a crucial attribute of financial assets, in US market. In particular, this research attempts to address a number of issues in the theoretical study of liquidity, some of which even still matters for debate.

The empirical results in Chapter 3 suggest that the significance of liquidity on asset returns is time specific, in other words, the heterogeneity between liquidity components exhibits a Business Cycle effect. In particular, the liquidity risk premium is strengthened during downturns of the market conditions, as the association between the asset liquidity and return in the cross-sectional dimension is relatively stronger in the period of lower market liquidity. Besides, the analysis is carried out that focuses on the interrelationship between the market-wide liquidity components and the market dynamics, and some interesting Granger causality relationship is detected. Specifically, price impact components are Granger caused by transaction costs and trading activity, but do not Granger cause trading activity. Moreover, the Granger causality detected in this section also explains that market past performance is caused by liquidity, especially the dimensions of trading activity and price impact, and subsequently, the market-wide trading activity affects the market portfolio most recent and further performance. These findings for liquidity measures in this comparative analysis establish a significant step towards the understanding of liquidity measures in a more systematic and consistent setting, and can be a good starting point for constructing more robust liquidity measures.

Based on a negative relationship between volatility of liquidity and asset returns, Chapter 4 extends this finding and provides a comparative analysis of the volatility of liquidity risk

through an asset pricing framework considering several dimensions of liquidity, such as transaction cost, trading activity and price impact. The empirical findings, consistent with the literature, provide evidence of heterogeneity across various liquidity components and volatility specifications. In addition, by extracting the commonality of volatility of liquidity across individual assets via principal component analysis, the systematic components of volatility of liquidity are examined accordingly. Finally, a mimicking portfolio is constructed and used to track the systematic risk of volatility of liquidity, providing evidences that the latter is priced in asset returns.

Chapter 5 studies the impact of market-wide liquidity volatility on momentum profit. It is examined by investigating whether the volatility of market liquidity dominates the market liquidity level in terms of affecting and predicting the momentum profit. Besides, it is determined that the impact is state-dependent; in particular, the impact of the fluctuation of the market liquidity on the momentum payoff is stronger when the market volatility or the illiquidity is higher. Finally, by a closer inspection of the momentum crash event in 2009, it is observed that the volatility of market liquidity increases sharply a couple of months before the crash, while stays stable during and after the crash.

This thesis provides implications for investment perspective in terms of the trading strategies based on liquidity as well as momentum. For instance, the performance of the liquidity measurement is time-varying associated with market conditions. Moreover, the fluctuation of market liquidity, i.e., the volatility of liquidity, should also be considered for pricing issues. The empirical results suggest that the asset, of which the liquidity fluctuates heavily, usually has lower returns; this indication applies to six popular liquidity measures according to the empirical results. More importantly, investors could make profits by reversing the momentum trading strategy in momentum crash periods.

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This thesis is dedicated to my sweet heart daughter Alyssa.

Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Signature

Yuping Huang

Chapter 1

Liquidity in Equity Markets

1.1 Introduction

This thesis aims to explore stock liquidity, a crucial attribute of financial assets, and US market will be the main study object. The liquidity of an asset is recognised as its easiness of to be traded, and it has threefold indications: the trading cost, the trading speed and the price impact caused by trading. In equity markets, the effect of liquidity comprises asset returns and trading strategies, among others. In order to better understand the mechanism, this thesis makes an attempt at answering the following questions. First, how do the liquidity measures of three categories perform regarding the risk-return trade-off? Second, what are the driving forces behind the heterogeneity of liquidity measurement, and whether the market-wide characteristics are responsible for the time-varying performance of liquidity and its measures? Third, is the commonality of asset liquidity volatility priced in asset returns, and is the volatility of market-wide liquidity priced in asset return? Fourth, does the volatility of market-wide liquidity impact momentum profit?

The liquidity originates from exogenous transaction costs, inventory risk and private information. The brokerage fees/taxes incurred during the trading should be included in the transaction prices. The inventory risk serves another source of liquidity, as to the seller the market maker imposes the holding cost of assets, of which the prices are constantly changing. On the opposite, the nature of private and hence asymmetric information is a neutralizing fact of the liquidity: either or both sides of market participators are afraid of being exposed to the risk of losing money due to the private information the other side may possess, thereby reluctant to trade.

The effect of liquidity in trading has been well observed. A rational investor would always prefer to trade on a liquid state, and there are pervasive evidences correlating heavier trading volumes and higher market liquidity (Pereira and Zhang (2010)). On the other hand, the state of low liquidity usually leads to lower asset prices, which is less favourable for investors, who would then require higher return to compensate for holding illiquid assets. Constantinides (1986) defines the liquidity premium to be the compensation to investor so that he is indifferent between a perfect liquid asset and an asset with certain liquidity risk. More often than not, the liquidity of a market is under constant mutation, and thus investors may require additional compensations for being exposed to such a liquidity risk. Therefore, it would be reasonable to assume that all investors take liquidity in trading into consideration and make trading strategies accordingly.

Apart from the above-mentioned trading issues, liquidity helps us in understanding asset pricing. In empirical examinations, for example, liquidity well explains the cross-sectional returns of assets that have different liquidity, as well as the relationship between liquidity and equity returns in the time-series dimension.

1.2 Liquidity Measures Comparison

There is little doubt that the liquidity measures are important for the quantitative studies of asset liquidity. Since liquidity reflects the easiness of an asset to trade at a low transaction cost with little price impact, the concept includes trading quantity, trading speed, trading cost and price impact. Numerous measures have been considered in literature. For instance, Amihud and Mendelson (1986) propose the annual bid-ask spread as a proxy of liquidity; Chordia, Subrahmanyam and Anshuman (2001), Nguyen, Mishra, Prakash and Ghosh (2007) and Pereira and Zhang (2010) approach liquidity through turnover ratio; Stoll (1978) and Datar, Naik and Radcliff (1998) suggest that the quantity of trading volume reflects the liquidity; Kyle's (1985) starts the studies in the dimension of price impact; Amihud (2002) proposes the ratio of return to dollar volume; while Florakis, Gregoriou and Kostakis (2011) suggest the return to turnover ratio. These measures roughly cover three dimensions: transaction cost, trading activity and price impact. To more accurately analyse these dimensions, researchers have used the absolute spread and the relative spread to assess the trading friction with respect to the transaction cost, the turnover ratio and the dollar volume that are associated with spread, and the ratios of return to dollar volume or return to turnover ratio with the intention of measuring the price impact by order flow as these ratios represent the price response to order flow. These measures are correlated with each other, though each emphasizing different aspects.

The empirical evidence of the relationship between the liquidity and asset return is provided in literature. The main strand of study indicates that less liquid assets are allocated to investors with longer investment horizons and the asset expected return is an increasing function of the illiquidity. Amihud and Mendelson (1986), Datar, Naik and Radcliff (1998), and Brennan, Chordia, and Subrahmanyam (1998) use data from US stock exchanges and investigate the cross-sectional effects of turnover ratio controlling several firm characteristics and they found that turnover ratio is negatively related to expected asset returns. There are nevertheless conflicting evidences reported, e.g., Conrad, Allaudeen, and Cathy (1994), Lee and Swaminathan (1998), Rouwenhorst (1999) and Brown, Crocker, and Foerster (2009) investigate the turnover ratio and asset return and find that the turnover effect is insignificant and even positive. These conflicting evidences are not consistent with the intuition of liquidity. A possible explanation is that the turnover ratio is positively associated with illiquidity, as implied by Stoll (1978), who applies the turnover ratio metric to represent the adverse information effect. His observation is that private information would lead to a higher level of trading relative to the outstanding shares. Thus, a higher level of turnover ratio indicates the adverse information, which results in higher spread and higher illiquidity.

Instead of focusing on the liquidity of individual assets, Chordia, Roll and Subrahmanyam (2001) study the time-series properties of market-wide aggregate liquidity by examining the determinant explanatory variables of liquidity. Specifically, the market volatility and contemporaneous market moves are chosen because they influence the inventory risk, which is one of the sources of liquidity. They notice that the liquidity descends significantly in down markets, while the increment of market volatility is related to the decrement of trading activity and trading cost. The time-series behaviour of aggregate liquidity, which is observed by Chordia Roll and Subrahmanyam's (2001), implies that the market characteristics have impact on market liquidity and are potentially associated with the performance of liquidity measures accounting the liquidity risk premia.

The above-mentioned studies lead us to the following questions. Does the relationship between liquidity and asset return hold across different liquidity measures? Now that liquidity is persistent, is this relationship constant or varying over time? How the different dimensions of liquidity are affected, especially by various explanatory variables of liquidity proposed in literature?

One of the objectives of this thesis is to investigate empirically the liquidity effect on the risk-return trade-off. Towards this end, the liquidity premium dynamics are investigated on an asset pricing framework. More specifically, the purpose is to quantify the liquidity risk premium comparatively with respect to its main dimensions and to investigate its time dynamics.

A cross-sectional analysis is conducted on US market data, specifically for the period from 1962 to 2011 considering the US Business Cycle, and I further consider the liquidity measures at a market-wide level and analyse their causality with aggregated market characteristics. In particular, the Fama-MacBech cross-sectional regressions are employed to estimate the magnitude of liquidity premia through different liquidity measures. Furthermore, in order to more accurately determine the time-varying effect of liquidity on asset return, the whole horizon is divided into several sub-periods on the basis of the Business Cycles.

The empirical results from cross-sectional examinations are consistent with the foundations of liquidity measures though several structural changes that have taken place during the examined time period. Specifically, the empirical results in this thesis suggest that the significance of liquidity is time specific, in other words, the heterogeneity between liquidity components exhibits a strong Business Cycle effect. For instance, the liquidity risk premium is strengthened during downturns of the market conditions, as the association between the asset liquidity and return in the cross-sectional dimension is relatively stronger in the period of lower market liquidity.

In addition to the comparative analysis of the liquidity risk premia, a time-series analysis is conducted and it aims to consider the potential bidirectional relationships between liquidity and market characteristics. By employing a VAR representation of the market-wide liquidity measures and the market characteristics, the potential causality effects are investigated between the liquidity components and the market dynamics. In particular, being interested in detecting the cause of the variation of the liquidity effect on asset returns, one is motivated to conduct the Granger Causality test among the market-wide liquidity measures from the three dimensions and the market characteristic variables.

It is detected that bidirectional Granger causality exists within the same category of liquidity measures, and between transaction cost and price impact measures. Price impact variables are Granger caused by transaction costs and trading activity, but do not Granger cause trading activity. Furthermore, the Granger causality among market liquidity and state variables also helps to explain that market past performance is caused by liquidity, especially the dimensions of trading activity and price impact, and subsequently, the market-wide trading activity affects the market portfolio most recent and further performance.

1.3 Volatility of Liquidity and Pricing Issue

The systematic component of liquidity on an aggregated market level has been well studied. Chordia, Roll and Subrahmanyam (2001), Hasbrouck and Seppi (2001), and Huberman and Halka (2001) find commonality of order flow and liquidity across assets. The empirical finding of liquidity commonality motivates Chordia, Subrahmanyam, and Anshuman (2001) to investigate the second moment of asset liquidity and its relationship with asset returns on a cross-sectional level. The second moment of asset liquidity represents the fluctuation of liquidity, and incorporates two components - systematic and idiosyncratic. Beardsley, Field and Xiao (2012)[1] claim that both liquidity level and higher moments of liquidity are affect asset returns and optimal portfolio construction.

Chordia et al. (2001) are the first who introduce the investigation of volatility of liquidity and its explanatory power with respect to asset returns. They recruit liquidity measures relevant to trading activity (dollar volume and turnover ratio) and find a solid but "puzzling" negative cross-sectional relationship between the volatility of liquidity and asset returns on an asset pricing model framework. They define the volatility of liquidity as the standard deviation of the 36 lagged monthly observations of dollar volume and turnover ratio divided by the mean of the prior 36 monthly observations. An alternative risk specification is also examined through the estimation of the conditional volatility of dollar volume and turnover ratio using a GARCH (1, 1) model as a robustness check.

Negative relationship between the volatility of liquidity and the expected returns has been observed, though a positive one is usually expected; the intuition that investors require higher returns to compensate the liquidity risk - the fluctuation of liquidity level, which is suggested by Hasbrouk (2006) when studying the volatility of turnover. This somewhat counterintuitive relationship may be attributed to the clientele hypothesis of Merton (1987) regarding which securities that attract many investors would yield lower returns. Thus, variability of liquidity metrics could potentially account for the heterogeneity of the clientele holding the share and consequently, higher variability would imply a greater heterogeneity among the investors who hold the specific security, yielding lower returns.

The negative impact of volatility of liquidity on asset returns is further investigated by Pereira and Zhang (2010). They adopt the price impact component of liquidity (return to

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[1] Beardsley, Field and Xiao (2012) incorporate one to four moments of liquidity into optimal portfolio construction, and they claim that first moment of liquidity is liquidity level, the second represents liquidity commonality, the third moment indicate the asymmetry in liquidity commonality (e.g. flight to liquidity effect), and fourth moment, Kurtosis in liquidity, represents severe outliers and variation in liquidity.

dollar volume) for a multi-period investor who requires additional compensation for the adverse price impact of trading. Most importantly, they provide evidence that the puzzling negative effect is consistent with a risk-averter, fully rational and utility maximizing investor with a CRRA utility function. Based on daily, instead of monthly, liquidity observations, Akbas, Armstrong and Petkova (2011), in one of their manuscripts, propose the use of an alternative measure of liquidity risk. They find that the idiosyncratic component of risk of liquidity is priced positively on an asset pricing framework.

A possible explanation for the empirical finding in literature of the negative association between the volatility of liquidity and asset return is given in a manuscript by Barinov (2011), who argues that it is due to the positive correlation between turnover variability and aggregate return volatility, which is directly affecting the asset returns. Barinov (2011) examines the effect of liquidity volatility on asset expected returns, by other liquidity measures. He finds that the relationship between asset returns and liquidity volatility is mostly insignificant, unless employ turnover as the liquidity proxy. However, Blaua and Whitby (2013) provide evidence to support that the liquidity variability affects expected returns positively, when liquidity is measured by bid-ask spreads. They also claim that the liquidity variability is an important component of illiquidity.

This thesis investigates the informational content of the volatility of the liquidity measure, through the examination of several research hypotheses. The main work is a comparative analysis considering several dimensions of liquidity, including transaction costs, trading activity and price impact, and two alternative specifications of volatility of liquidity, Vol1 and Vol2, which captures the variation of daily liquidity within each month and reflects the fluctuation of liquidity of prior months, respectively.

With the aim of examining whether the volatility of liquidity is negatively related to the asset returns as the literature suggests, and whether this negative relationship holds across various liquidity measures, the experiments are conducted in a conventional Fama-MacBeth framework. It is detected that Vol1 holds the significant and negative relationship with asset return in the dimension of transaction cost of liquidity, while Vol2 is negatively associated with asset return when the liquidity is measured in the aspect of trading activity and price impact.

Furthermore, in order to determine the systematic risk of volatility of liquidity, I investigate potential commonalities of volatility of liquidity both within and across the examined liquidity measures metrics, following Korajczyka and Sadka (2008)'s approach by Principal Component Analysis (PCA). In other words, in addition to estimating common factors for each measure of volatility of liquidity individually, I also estimate common factors across all the six measures of liquidity. The idea of mimicking factor construction is from Ang, Hodrick, Xing, and Zhang (2006). Chapter 4 provides the evidence that the systematic risk of volatility of liquidity is priced in the asset returns.

Finally, an alternation of volatility of market-wide liquidity is studied in order to examine the pricing of systematic risk of volatility of liquidity. The volatility of market-wide liquidity is obtained by the similar construction of Vol1 and Vol2, but concerning aggregate market-wide liquidity instead of individual asset liquidity, and I term them as Mvol1 and Mvol2. It is found that the mimicking factors, which are relevant to Mvol1 and Mvol2, are priced in asset return, only in specific dimensions of liquidity.

1.4 Momentum and Volatility of Liquidity

Momentum is widely studied in literature, of which the work of Jegadeesh and Titman (1993) is the most cited. They examine the momentum effect of assets for the following months, and find that the assets which perform well in the past few months would continue to be winners, and those have low returns tend to perform poorly for the next few months. The momentum profit is generated by buying past winners and selling past losers, and this profit is not explained by conventional asset pricing models.

Literature suggests that the profit of the momentum portfolio is affected by market states. For instance, Cooper, Gutierrez, and Hameed (2004) display low momentum payoffs in high volatile market; the momentum crash occurs in the recovery market after downwards. Market liquidity is also related to the momentum profit, though the exact mechanism remains indecisive. Chordia, Subrahmanyam and Tong (2014) claim that the asset anomaly is reduced in liquid market as a result of active trading leading the arbitrage to be diminished, which means that the momentum anomaly is supposed to be negatively related to market liquidity. However, in a recent manuscript, Avramov, Cheng and Hameed (2014) provide opposite evidence that the momentum profit increases following illiquid market and declines when the market liquidity is high.

It is nature for one to associate the volatility of liquidity with the momentum payoff[2]. According to Pereira and Zhang (2010), the heavy fluctuation of liquidity results in more trading opportunities and strategies to adopt for agents. On the one hand, the volatility of market liquidity, along with the market liquidity, describes the market regime, i.e., the market states, to which the momentum payoff is potentially related. On the other hand, the investors could take advantage of the liquidity states, when more trading opportunities and strategies are adopted, so that the arbitrage of momentum might be affected in case that market liquidity is highly volatile.

[2] The momentum strategy is one of the trading strategies could be adopted, however, an investor may adjust his trading following other strategies, for instance, to buy assets with small capitalisation and to sell those with big size and to obtain the premium of SMB. In this study, only the MOM payoff is studied, but other anomalies are also very interesting and worthy being explored for further studies in the context of market liquidity or its volatility.

Therefore, I attempt to investigate the relationship between the momentum payoff and the volatility of market liquidity, in the presence of other market states including market illiquidity. The investigation is conducted in both time-series and cross-sectional dimensions. Specifically, I study the regressions of the volatility of market liquidity on momentum profits and on momentum effect coefficients, respectively. In other words, the two tests are implemented by time-series and cross-sectional regressions. The empirical results from the time-series and cross-sectional regressions convince that the high volatility of market liquidity leads to the reduction of momentum effect, otherwise, when the market liquidity stays stable, the price continuation is stronger and hence the momentum payoff increase. This conclusion applies to the momentum both in portfolio and individual stock level.

Furthermore, the negative association between the volatility of market liquidity and the momentum payoff is not constant but time-varying and state-dependent. By introducing two dummy variables, which represent the market regimes regarding market liquidity and volatility, into time-series regressions, the estimation results imply that the negative effect is stronger in volatile market state, and even much stronger when the market is illiquid.

Lastly, the volatility of market liquidity is also linked to the event of momentum crash. After putting the momentum crash event in 2007 under closer inspection, it is observed that the volatility of market liquidity climbs twice before the momentum crash, and stay relatively stable during and after the crash. The pattern of volatility of market liquidity could be viewed as the sign for the impending momentum crash, along with the up market return after downwards.

1.5 The Contributions

The potential contribution of this thesis could be summarized as follows.

First, the heterogeneity between liquidity components exhibits a strong Business Cycle effect. In particular, the liquidity effect on asset return is strengthened during downturns of the market conditions, as the association between the asset liquidity and return in the cross-sectional dimension is relatively stronger in the period of lower market liquidity.

Second, it is discovered that market-wide price impact variables are Granger caused by transaction costs and trading activity proxied, but price impact measures do not Granger cause trading activity variables. The Granger causality detected in this thesis also helps to explain that market past performance is caused by liquidity, especially the liquidity dimensions of trading activity and price impact, and subsequently, the market-wide trading activity affects the market portfolio's most recent and further performance.

Third, the empirical analysis the volatility of liquidity contributes to the existing literature by additionally providing evidence of the negative relationship between asset returns and volatility of liquidity, across various liquidity components and volatility specifications.

Fourth, this thesis provides evidence that the systematic risk of volatility of liquidity is priced in the asset returns, following methodology of Korajczyk and Sadka (2008) and Ang et al. (2006). This empirical finding offers mimicking factors to track the systematic risk of volatility of liquidity, in addition, allows further researchers consider it as a pricing factor.

Moreover, this thesis shed much light on the investigation of the momentum of asset returns. It is realized that in heavy fluctuation of market liquidity (i.e. the high volatility of market liquidity), the momentum profit of the following month decreases, while it increases after low volatility. This finding of the volatility of market liquidity dominates the market liquidity itself, in terms of the productivity of the momentum payoffs in the following months. Besides, a closer investigation of momentum crash provides us the insight of the volatility of market liquidity which is rising sharply before the momentum crash. One could consider the drying of market liquidity and the suddenly increasing highly volatile level of market liquidity as high market stress, which is viewed as the sign for impending momentum crash, addition to Daniel and Moskowitz's (2014) finding of up market returns after downwards as the sign of oncoming momentum crashes.

Finally, this thesis has implication for investment perspective in terms of the trading strategies based on liquidity as well as momentum. In particular, though the literature suggests that the assets with higher illiquidity require higher returns, my results imply that it is correct in general, but time-specific and depending on the market regime. The market characteristics are associated with the performance of the liquidity measurement, thereby determining the estimations of liquidity premium. Moreover, the fluctuation of market liquidity, i.e., the volatility of liquidity, should also be considered for pricing issues. The empirical results suggest that the asset, of which the liquidity fluctuates heavily, usually has lower returns; this indication applies to six popular liquidity measures according to the empirical results. More importantly, given the predictability of momentum crash by the market liquidity and its volatility, investors could make profits by reversing the traditional strategy. That is, buying past losers and selling past winners before the crash occurs could generate significant positive payoffs, as long as the prediction of the oncoming crash is accurate.

1.6 Outline

This thesis is organised as follows. Chapter 2 reviews the literature related to the effect of liquidity in equity market. Chapter 3 studies liquidity measures and their interaction with market characteristics. Chapter 4 studies the volatility of liquidity as well as its impact on asset returns. Chapter 5 studies the effect of the volatility of market liquidity on momentum profit, and in particular, the predictive power of momentum crashes. Chapter 6 closes the thesis with conclusion remarks.

Chapter 3 is devoted to the study of six liquidity measures: spread / relative spread, trading volume / turnover ratio, and return to dollar volume / return to turnover ratio, which are from three different dimensions, i.e., transaction cost, trading activities and price impact. The Fama-MacBeth method is employed in the examination of the impact of liquidity on asset cross-sectional returns by the six liquidity measures. Comparing liquidity premium across liquidity measures and across Business Cycles, it is found that the effect of liquidity on stock return by some liquidity measures differs in certain sub-periods. In other words, there exists a time-specific heterogeneity in terms of the liquidity constituents, though during non-tranquil periods illiquidity yields high returns. Specifically, the transaction cost has a positive effect on return in recent 20 years; the negative effect of trading activity on cross-sectional return works in the early 70s and whole 80s; while the effect of return to dollar volume ratio is different from its of return to turnover ratio on the asset returns. The varying effect from different periods of Business Cycles suggests that market information may influence the performance of liquidity measures, due to the market states and the macroeconomics conditions that vary over Business Cycles. I employ multivariable regressions and the Granger Causality test among variables of liquidity dimensions and market characteristics. The bidirectional causality exists within the same category of liquidity measures, as well as between the trading activity and the price impact. The price impact does not Granger cause the trading activity. Moreover, the bidirectional causality exists between market volatility as well as market return directions and the price impact or trading activity measures, but return-related indicators do not Granger cause the transaction cost proxies. Moreover, the Granger causality by the momentum proxies is strong to the trading activity, but not to the price impact or transaction cost dimensions.

Chapter 4 is focused on the volatility of liquidity. In order to fill the gap in the literature of liquidity volatility, I examine its impact on cross-sectional asset returns by more proxies of liquidity, employing the Fama-MacBeth method. I obtain the results of negative relationship between volatility and asset return. It is not a coincidence of the negative relationship, but it applies to all the six liquidity measures according to the empirical results. More importantly, based on the results by the principal component analysis (PCA), the commonality of volatility of liquidity across individual assets is detected. By following the approach of Ang, Hodrick, Xing and Zhang (2006), I conduct the test whether the commonality of volatility of liquidity is priced in asset returns. In addition, the volatility of market liquidity is also priced in asset returns.

Chapter 5 investigates the impact of market states to momentum profit, especially the fluctuation of market liquidity. It ascertains that the momentum payoff decreases when the market liquidity fluctuates heavily, while when the market liquidity stays stable the momentum profit increases holding other conditions same. By closer observations, I find the interesting patterns of market states before and during the momentum crash in 2009, which is due to the quicker and stronger reversal of loser portfolios than winner portfolios. In particular, market liquidity is extremely low and volatility of market liquidity climbs twice before the momentum crash, and stay relatively stable during and after the crash.

Chapter 2

Literature Review

The literature on liquidity is large, but I mainly focus on the papers which are related to the effect of liquidity on equity market. It is typical to begin from the source of liquidity, which is widely studied in the macrostructure papers. Besides, the studies which theoretically propose and empirically examine the liquidity measures are highly appealing, since the proxy of the liquidity is the basis of empirical studies. Apart from the liquidity level which is convinced to affect asset return, the liquidity risk also arouses the interest of practitioners and researchers, considering there could exist a systematic component and be priced in asset return. Finally, I concentrate on one of the anomaly, momentum, of which the trading strategy involves liquidity.

2.1 The Source of Liquidity

It displays some related market microstructure studies on the origins of liquidity, starting from the trading mechanism and the sources of liquidity.

It is generally agreed that the main sources of liquidity are brokerage fees/taxes during trading, the inventory risk and the private information (Amihud, Mendelson and Pedersen (2005)). The brokerage fees/taxes are exogenous cost and usually considered in the buyers' side, because they will eventually sell the securities and have to pay for the cost. When a securities owner intends to sell his holding securities, he has to wait for the buyers' presence in order to unwind his position, thus he is holding the inventory and has been exposed to the risk of price changes. The inventory risk is related to the investors' risk tolerance and market environment, including interest rate and market volatility. As for the private information in trading, it is a guessing game, because the traders in one side may worry that those in the other side have special information about market or underlying securities, and may become reluctant to trade. The impact of private information on liquidity has also been intensively studied, e.g., Bagehot (1971), Kyle (1985), and Easley and O'Hara (1987), Glosten and Harris (1988), Brennan and Subrahmanyam (1996) and Garleanu and Pedersen (2004).

According to Bagehot (1971), the market makers confront three kinds of transactors in market: 1) investors with special information; 2) investors who have no special information and trade only with the motivation of liquidity – exchange cash and securities; and 3) investors who trade on some information that they believe to be special but actually fully discounted on market. Bagehot (1979) claims that the first group of transactors always makes money from market makers, and large spreads between the bid and ask prices of market makers could lead to the decision of no trading by those investors, who act on special information. For market makers' own benefit, they have to earn more money from the second investors than the loss to the first ones: the larger spreads make more gains from liquidity-motivated investors and fewer losses to information-motivated investors. Given that fact that the bid-ask spread is decreasing with liquidity, the market makers always want to maximize liquidity for their own best. The information service persuades the third group of investors to trade on not-really-special information, thereby resulting in more market liquidity.

In terms of the first and second categories of investors, the market makers widen the spreads to enlarge the gain from uninformed investors, in order to compensate the loss to the informed investors, who are not identified by market makers before trading. The additional widened spread is an adverse-selection component; in other words, the market makers are faced with adverse selection. Copeland and Galai (1983) and Glosten and Milgrom (1985) raise this issue and conduct a comprehensive analysis. In the latter, an adverse-selection spread component is defined as a revision of expectation by the uninformed market makers, who change the expectation when suddenly realise they are actually trading with information-motivated investors. Glosten and Harris (1988) believe that such a component has permanent effect on price changes, as it is due to the revision of the market makers' expectation. An adverse selection problem is consequently created: informed traders with bad news are likely to sell, while informed traders with good news have an incentive to buy.

Garleanu and Pedersen (2004) quantify the bid-ask spread and information. An uninformed non-owner submits the limit order to buy: $bid_t = \delta(\hat{x} + S_{t+1} - B_{t+1})$, which is the next discounted (by the factor δ) expected dividend $\hat{x}$ plus the owner value S_{t+1} and reduce the non-owner value B_{t+1}. Note that $\hat{x}$ is conditional on the sale of the informed owner, i.e., $\hat{x} = E(x_{t+1} | sale)$. On the other hand, an informed owner submits market order to sell when his prediction of keeping value is worse than the continuation value from sale. That is $bid_t + \delta B_{t+1} \geq \delta(x_{t+1} + \sigma_{t+1} + S_{t+1})$, where σ_{t+1} denotes the agent's liquidity needs in this period. Thus, the same variables could be offset and the equation would be $x_{t+1} + \sigma_{t+1} \leq \hat{x}$, that is the informed owner will sell if the his prediction of dividend according the information and his liquidity needs is worse than the expected next dividends. Therefore, equilibrium is achieved by equating the uninformed non-owner's expectation and the informed owner's order:

$$\hat{x} = E(x_{t+1} | x_{t+1} + \sigma_{t+1} \leq \hat{x}) \tag{2.1}$$

For the ask price submitted by the uninformed owner and the informed non-owner is similar that the equilibrium is $\breve{x} = E(x_{t+1} | x_{t+1} + \sigma_{t+1} \geq \breve{x})$, where $\breve{x}$ is the expected dividend on a purchase order.

One can summarize as:

The Uninformed non-owner submits:

$$bid_t = \delta(\hat{x} + S_{t+1} - B_{t+1}) \tag{2.2}$$

The Informed owner sells if:

$$x_{t+1} + \sigma_{t+1} \leq \hat{x} \tag{2.3}$$

The Uninformed owner submits:

$$ask_t = \delta(\breve{x} + S_{t+1} - B_{t+1}) \tag{2.4}$$

The Informed non-owner buys if:

$$x_{t+1} + \sigma_{t+1} \geq \breve{x} \tag{2.5}$$

where $\hat{x}$ and $\breve{x}$ are the expected dividends given the informed investors' sale and buy, respectively; Garleanu and Pedersen (2004) solve the two equilibria for both sale and purchase.

Moreover, the values of ownership and non-ownership are given by

$$S_t = \sum_{s=t+1}^{T} \delta^{s-t}(\mu + \sigma^+ - \widehat{c}) \tag{2.6}$$

that is the present value of future dividend $\mu = E(x_t)$ and the private benefit σ^+, reduced by the future allocation cost $\widehat{c}$.

$$B_t = \sum_{s=t+1}^{T} \delta^{s-t}(\sigma^+ - \breve{c}) \tag{2.7}$$

where $\breve{c}$ denotes the buy-side allocation cost.

Specifically, the allocation costs are due to the misallocation of the asset, which is opposite to the investors' private value.

Thus, the bid and ask prices submitted could be computed as:

$$bid_t = -\delta(\mu - \hat{x}) + \sum_{s=t+1}^{T} \delta^{s-t}\mu - \sum_{s=t+2}^{T} \delta^{s-t}(\widehat{c} - \breve{c}) \tag{2.8}$$

and

$$ask_t = -\delta(\breve{x} - \mu) + \sum_{s=t+1}^{T} \delta^{s-t}\mu - \sum_{s=t+2}^{T} \delta^{s-t}(\widehat{c} - \breve{c}) \tag{2.9}$$

Nevertheless, in a full-information competitive market, the bid price equals to the ask price, and thus their values are:

$$E(\delta x_{t+1} + \sum_{s=t+2}^{T} \delta^{s-t}\mu) = \sum_{s=t+1}^{T} \delta^{s-t}\mu \tag{2.10}$$

The private values are not priced in the full information equilibrium as $\widehat{c} = \breve{c} = 0$.

The bid-ask spread in an asymmetrical information market is different from that of a full-information market, where the spread is zero. It can be concluded that the adverse selection affects the required return not through the bid-ask spread directly.

In asymmetrical information environment, the bid price is lower than that of a full-information market, while the ask price is higher. The bid-ask spread only exists in an asymmetrical information market. The differences are due to the bias of bad news motivating sale/good news motivating buying, and the allocation costs, i.e. $R_{i,t} = r^f + f(\hat{c}, \breve{c})$.

2.2 Liquidity Measures

The definition of liquidity is not specified but most of the researchers recognise it as the easiness to trade. It is widely agreed that the high liquidity indicates the situation when the assets can be transacted fast with low cost and little impact on prices. The extreme case is the risk-free asset, considering it is can be traded at any time with no cost and impact. Therefore, there are at least three aspects of liquidity: trading speed/quantity, cost to pay and the impact on prices. For either the researchers or the practitioners, one of the most popular topics regarding liquidity is how to measure it. Amihud, Mendelson and Pedersen (2005) point out that "liquidity is an elusive concept and is hard to measure", and also claim that the data availability is one of the constraints to construct a perfect measure.

In this section, the majority of popular liquidity measures in literature are reviewed. For the purpose of assessing the correctness and the preciseness of the measures, one can study through the effect of liquidity on asset by the specific measure, considering people is interested in not only the liquidity itself, but also the liquidity effect. Hence, in this thesis, I will review how the liquidity measures are constructed, and the corresponding effect of liquidity on asset return in empirical literature.

2.2.1 Spread

The most frequently used liquidity measure in literature is the bid-ask spread, which is the approximate proxy of the cost to liquidate the security, and also reflect the degree of information asymmetric between two sides of trades.

The liquidity studies regarding the transaction cost start from Amihud and Mendelson (1986). The basic idea is that the price of asset is simply the present value of all future expected dividends in a no-friction perfect market. However, the streams of transaction cost will be taken into account of the value of asset. Besides, the motivation of each trade could be the need for cash or the speculation. Thus, the expected trading frequency μ should also be considered when value an asset - weight the transaction cost. Therefore, the price of asset equals to the present value of dividends stream and transaction costs stream, that is, the expected return of an asset equals to the risk-free rate, plus the relative transaction cost: $E(r_i) = r^f + \frac{\mu C_i}{P_i}$, where $E(r_i)$ is the expected return of asset i, r^f is risk-free rate which equals to the perfect liquid asset return, C_i is the present value of all future transaction cost and P_i is the prices of assets, μ denotes the trading intensity (which is related to the reciprocal of holding period T). $\frac{C_i}{P_i}$ is the relative transaction cost. The last term $\frac{\mu C_i}{P_i}$ is per-period percentage transaction cost.

The intuition from the above equation is that the asset expected return is a function of transaction cost. Hence, Amihud and Mendelson (1986) employ the relative bid-ask spread RS_i as a proxy of transaction cost: $\frac{bid_i - ask_i}{P_i}$. Instead of study individual assets, Amihud and Mendelson (1986) focus on portfolios. Specifically, Amihud and Mendelson (1986) average the beginning and end-of-year relative spread for each of year as the annual spread of a single asset, and group the assets into portfolios on the basis of relative spreads of previous years. Thus, the portfolios' relative spreads and monthly excess returns are calculated accordingly across the assets. In empirical studies, Amihud and Mendelson (1986) investigate the relationship between portfolios returns and the relative spreads after controlling market beta, and find that the portfolio returns increase with the spread, and estimation of slopes even also increases with the portfolio spreads. The latter finding is explained by the clientele effect, which indicates that in equilibrium, assets with higher transaction costs are allocated to the agents with longer holding horizons. Regarding the positive relationship between portfolio returns and spreads, Amihud and Mendslson (1986) claim that it results from the required compensation for securities with high bid-ask spread.

Many other papers follow Amihud and Mendslson's (1986) light to employ the relative spread as a proxy of asset liquidity. Amihud and Mendslson (1989) add an additional term in regression in order to examine whether residual risk of return dominates the spread effect. According to Rozeff and Kinney (1976), Kein (1983), Reinganum (1983) and Roll (1983), the effect of market risk on expected return is more reliable in January in every year. Eleswarapu and Reingnum (1993) replicate the empirical study of Amihud and Mendelson (1986) and discover that the effect of relative spread on asset return is only significant on Januarys. Eleswarapu (1997) provides evidence that the relationship between the relative spread and asset return is even stronger in Nasdaq stocks than in NYSE and AMEX stocks. Huberman and Halka(2001) and Korajczyk and Sadka (2008) Chordia, Roll and Subrahmanyam (2000, 2001) study the time-series properties of market-wide aggregate liquidity level on the daily basis, and test commonality of liquidity through the liquidity measures including spread. Hasbrouck and Seppi (2001), Huberman and Halka(2001) and Korajczyk and Sadka (2008) investigate the systematic liquidity. In specific, the common and systematic components of liquidity are extracted and aggregated from a set of measures, inclusive of the spread and relative spread.

In addition to represent the transaction cost, the relative spread could also reflect information asymmetric between two sides of trades. Considering that buying orders at the ask prices imply good news signals while selling orders of bid prices indicate possibly bad news, uninformed market participates reduce the bid price or increase the ask price in order to protect a potential loss to the informed traders. That is, the larger spreads induce larger gain (from uninformed investors) and less loss (to informed investors) of market makers. Copeland and Galai (1983) and Glosten and Milgrom (1985) define that the additional widened spread is a adverse-selection component on the purpose of protection when the market makers deal with the informed traders, and it is resulting from the revision of the market makers' expectation. On the other hand, the enlarged spread makes the transaction less attractive and the trading activity of informed and uninformed traders consequently is dampened, thus, the market may trend downward in some circumstances. Hence, the market makers have to formulate optimum choices and impose the apropos bid-ask spread.

One way or the other, the spread is an appropriate measure of liquidity, as long as it is a proxy of the transaction cost; in addition to this, spread reflects (the degree of) asymmetric information and indicates the perspectives of the market makers.

2.2.2 Kyle's λ

In order to more precisely capture liquidity premium response to the adverse selection, Brennan and Subrahmanyam (1996) estimate the illiquidity measure using intraday transaction data and obtain variable and fixed components of the transaction costs. The methodologies follow Glosten and Harris (1988) as well as Hasbrouck (1991) and Foster and Viswanathan (1993). The variable component λ is related to order flows (signed trading volume), while the fixed component is ψ and it is estimated by price change and trading signs.

According to Glosten and Harris (1988), asset expected value m, order flow q, transaction price p, and trading sigh D have the following relationships:

$$m_t = m_{t-1} + \lambda q_t + y_t \tag{2.11}$$

$$p_t = m_t + \psi D_t \tag{2.12}$$

$$\Delta p_t = \lambda q_t + \psi [D_t - D_{t-1}] + y_t \tag{2.13}$$

where λ denotes the variable component of the transaction cost and measures the adverse selection; D_t denotes order signs - (+1) for buying and (-1) for sale. λ measures the price impact, being smaller for more liquid assets. ψ is estimated as the fixed transaction cost; ψ reflects the fixed transaction cost and it is unrelated to order size. Following this Kyle-type model, the cost of trading securities is calculated by $C_q = \lambda q / P$, which equals the market depth times the trading size divided by the monthly average price. Moreover, considering the cases of extreme trading size, a alternative measure is employed: $C_n = \lambda n / P$, where n denotes the number of shares outstanding. Another two liquidity variables considered by Brennan and Subrahmanyam (1996) are bid-ask spread d / P and fixed trading cost λ / P.

Furthermore, the relationship between return and illiquidity risk is estimated in the Fama-French framework. Consequently, there are four estimated liquidity variables in all to test in the Fama-French model. Firstly, to form five portfolios based on size and subdivide each into five according to λ ; and then to observe that portfolio returns are negatively correlated with the spreads and the fixed trading costs; in addition, within the size groups, λ is almost perfectly negative related to the four liquidity variables, respectively.

In regression estimations, combinations of the liquidity variables entry the below regression:

$$R_{i,t} = \alpha + \sum_{k=1}^{N} \beta_L L_{i,k} + \beta_{MKT} MKT_t + \beta_{SMB} SMB_t + \beta_{HML} HML_t + \varepsilon_{i,t} \tag{2.14}$$

where L_k stands for one of the liquidity variables and could also be the combinations of the four variables.

The first regression includes the spread to capture liquidity risk, as suggested by Amihud and Mendelson (1986), but the estimation of coefficient tends to be negative and opposite of Amihud and Mendelson's (1986) results. The opposite results could be due to different pricing frameworks in which they are working – Amihud and Mendelson (1986) employ CAPM, while Brennan and Subrahmanyam (1996) study under the Fama-French framework. Then, to included the spread, C_q and λ / P in the regression as the liquidity measure, the effect of spread is still negative but the latter two are both significantly positive.

The next regression is for the purpose of taking potential nonlinearity into account, thus the logarithms of both the C_q and λ / P , along with the spread variable are added into regressions. It is discovered that the results of spread effect and the transaction variable C_q are consistent with previous one, but the fixed cost λ / P is less significant; it suggests that horizon clientele may not be so important.

Another conduction of C_q and λ / P is to square them, and the estimation of coefficient results turn out to be interesting. The coefficient estimate of ${C_q}^2$ is significantly negative, and it confirms the concave relation suggested by Amihud and Mendelson's (1986). However, the coefficient of squared λ / P is again insignificant.

Finally, to recover the variables of firm size factor and price level, which are originally omitted in the Fama-French three-factor model, along with the spread variable and the squared C_q and λ / P components. The estimation coefficients of C_q and λ / P are not different from those from the last test, while the spread effect tends to be less significant with the presence of the size factor and the price level variables, which appear to be insignificant and significantly negative, respectively. By alternative measure of C_n, the results are similar to that of C_q.

In one word, the transaction cost of both the variable and fixed components have positive effect on asset returns, along with other significant risk factors.

2.2.3 Trading Activity

Apart from the aspect of transaction cost, trading activity also reflects the degree of liquidity. Chordia, Roll and Subrahmanyam (2001) suggest that liquidity is related to the trading activity according to numerous market microstructure papers. Among numbers of trading activity indicators, dollar volume and turnover ratio are alternative liquidity measures.

The dollar trading volume, derived from multiplying the total number of shares traded by average price per share, is firstly studied in Stoll (1978) which claims that the trading volume is the most important determinant of bid-ask spread. The latter is decomposed into three variables - inventory cost, order processing cost and adverse selection cost. Stoll

(1978) considers that the inventory cost or holding cost of stocks is a function of holding period, in turn, the holding period is a function of trading volume since it is easy for traders to reverse their position if the asset is being traded heavily. Thus, mathematically, the spread is negatively related to the dollar volume. Moreover, Glosten and Harris (1988) provide evidence that the adverse selection cost is a significant component of bid-ask spread, as well as trading size (order flow) is inversely related to spread. Brennan and Subrahmanyam (1996) estimate the transitory and permanent components of transaction cost as illiquidity measures and they claim that the trading volume is a primary determinant of the adverse selection cost of transaction. Dollar volume measures the speed of transaction to unwind position. In particular, low dollar volumes in specific transactions indicate illiquidity, since it could be difficult to get out of the position and trading opportunities are fewer than high dollar volume case; likewise, high dollar volume implies high liquidity. Higher volume typically results in narrower spread, less slippage (slippage is the difference between the last trade price and the price realized by the next order), and less volatility, according to the study of Chordia, Roll and Subrahmanyam (2000), which documents a strong cross-sectional relationship between dollar volume and various measures of the bid-ask spread and market depth.

The use of the dollar volume as liquidity measure is popular in literature. Brennan, Chordia, and Subrahmanyam (1998), as well as Chordia, Subrahmanyam and Anshuman (2001) examine the explanation power of stocks' non-risk characteristics relative to the APT benchmark. A few non-risk characteristics are considered in the regressions, including firm size, stock price, B/M ratio, dividend yield, three momentum-based lagged returns, and the dollar trading volume to measure liquidity. The model to be examined is

$$E(R_i) - R_f = \alpha + \sum_{k=1}^{L} \lambda_k \beta_{ik} + \sum_{m=1}^{M} c_m Z_{im} \tag{2.15}$$

where λ_k is risk premium for factor k, β_{ik} is the loading of security i on factor k, c_m is premium for per unit of characteristic m, Z_{im} is the value of non-risk characteristic m of stock i. The literature argues that the dollar trading volume provides a better measure of liquidity than the bid-ask spread and dataset is also more accessible on the monthly or daily basis.

Regarding the turnover ratio as an alternative proxy of liquidity, this idea originates from Amihud and Mendelson's (1986) proposition. It suggests that, in equilibrium, assets with larger spread are allocated to the investors who are with longer holding period or longer horizons. In addition, Atkins and Dyl (1994) find that stocks' average holding horizon and spread has a positive relationship. On the other hand, the turnover ratio is the reciprocal of average holding period and related to how quickly a dealer expects to turn around his position.

A few papers employ turnover ratio as the proxy of liquidity. Datar, Naik and Radcliff (1998), Chordia, Subrahmanyam and Anshuman (2001), Nguyen, Mishra, Prakash and Ghosh (2007) and Pereira and Zhang (2010) use turnover ratio to measure liquidity, and they all suggest that lower turnover ratio indicates higher liquidity. Datar et al (1998) predict that lower turnover ratio is related to higher expected returns. The stocks' monthly turnover ratio is obtained as value of the average monthly trading volume over the recent three months divided by the number of shares outstanding of that month. Nguyen et al (2007) also find a significant effect of liquidity on returns when they use the turnover ratio as the liquidity proxy and they conduct both time-series and cross-sectional regressions tests to examine the pricing.

However, Conrad, Allaudeen, and Cathy (1994), Lee and Swaminathan (1998), Rouwenhorst (1999) and Brown, Crocker, and Foerster (2009) also investigate the turnover ratio and asset return, but results are not consistent with others.

2.2.4 Price Impact

Reminding of the illusive description of liquidity, i.e. high liquid asset is traded fast at low cost and imposes little impact on prices, one would study the liquidity from the aspect of price impact. Saying differently, the transactions of perfectly liquid assets would not change corresponding prices, while the larger price changes during trading is related to those assets with low liquidity. Hence, researchers propose the price impact as one of the appropriate measures of liquidity. Starting from Kyle's(1985) λ which is a decomposition of transaction cost and also indicates the price change per unit of net order flow in stock market, the literature focuses the price impact through a number of proxies, including Aminvest ratio, Amihud (2002) measure, and the Florakis, Gregoriou, and Kostakis (2011) measure. Besides, a recent paper of Ben-Rephael, Kadan and Wohl (2015), which point out that the liquidity itself is largely improved over time, includes inflation adjustment factor in Amihud measure considering that the cumulative inflation is 630% from 1964 to 2011, though the inflation adjustment does not affect estimation of liquidity premium.

Aminvest ratio is the ratio of assets dollar volume divided by absolute return, implying how much dollar volume is required to move a stock's price up or down by one percentage. A high ratio implies that large amounts of stock are traded with little movement on prices, thus, the stock is very liquid. The Aminvest ratio is popular among professional investors.

Amihud (2002) proposes the daily ratio of absolute stock return to its dollar volume as the measurement of price impact by order flow. The measure of stock illiquidity in Amihud (2002) involves the return and the dollar volume, instead of the bid-ask spread, signed order flow or other indicators which require microstructure data. This measurement represents the price response to order flow and it is consistent with the liquidity ratio. Moreover, this measure equips the usage of highly accessible daily data.

Yearly illiquidity measure $ILLIQ_{iy}$ for stock i is calculated by absolute daily return of stock i and its daily dollar volume $VOLD_{ivyd}$, and averaged by the number of trading days D_{iy} in year y:

$$ILLIQ_{iy} = (1/D_{iy}) * (\sum_{t=1}^{D_{iy}} \left| R_{iyd} \right| / VOLD_{ivyd}) \tag{2.16}$$

Moreover, the market illiquidity in year y is calculated as follows:

$$AILLIQ_{y} = (1/N_{y}) * \sum_{t=1}^{N_{y}} ILLIQ_{iy} \tag{2.17}$$

where N_y is the number of stocks in year y.

The daily illiquidity of individual stock is measured by the return for per dollar volume. Basically, an annual measure is constructed based on a daily measure, and market liquidity is averaged across all of the stocks in market.

Amihud (2002) examines the effect of market illiquidity on stocks expected excess return by lagged illiquidity and unexpected illiquidity in regression:

$$(RM - Rf)_y = g_0 + g_1 \ln AILLIQ_{y-1} + g_2 (\ln AILLIQ_y - c_0 - c_1 \ln AILLIQ_{y-1}) + \varepsilon_y$$

(2.18)

where RM_y is annual equally-weighted market return and Rf_y is one-year Treasury bill yield of the beginning of year y.

Florakis, Gregoriou and Kostakis (2011) propose another price impact ratio as an alternative measure of liquidity, following Amihud's (2002) Return to Volume (R to V) ratio. Specifically, the Return to Volume ratio is modified by the Return to Turnover ratio

(R to TR), in order to insulate size effect and consider trading frequency in the new measurement.

$$RtoTR_{it} = \frac{1}{D_{it}} \sum_{d=1}^{D_{it}} \frac{|R_{itd}|}{TR_{itd}} \tag{2.19}$$

where TR_{itd} is the turnover rate of stock i at day d of month t. This measure, reflecting the price impact similar to the ratio of return to dollar volume, indicates the response of stock return to one percent of turnover rate; that is, the stock with greater ratio of return to turnover is more liquid than that with lower ratio. The turnover rate hereby has some advantages, being free of size-bias and comparable across assets. Moreover, this measure of return to turnover ratio captures the trading frequency by involving the turnover rate in the euqation. Amihud and Mendelson (1986) provide the evidence that both the transaction cost and the trading frequency determine the liquidity premium. It is more appealing of the measure of return to turnover ratio in empirical studies, given the recently observed trend of reducing transaction cost and increasing trading frequency.

2.3 Liquidity Risk: Commonality

The liquidity research, especially which focuses on transaction cost and trading activity, has prevailed in market microstructure study. In particular, it discusses that the transaction cost and trading activities commoves across assets. Chordia, Roll, and Subrahmanyam (2000) claim that the liquidity is more than an attribute of single assets, and the researchers hence turn to study the liquidity on market-wide concept. Considering inventory risk as a part of the source of liquidity as analytically discussed in Section 2.1, Chordia et al. (2001) indicate that market interest rate and volatility impacts the inventory risk, which leads to the co-movement of individual asset liquidity. When a securities owner intends to sell his holding securities, he has to wait for the buyers' presence in order to unwind his position, thus he is holding the inventory and has been exposed to the risk of price changes. The inventory risk is related to the investors' risk tolerance and market environment, including interest rate and market volatility. Hence, if the inventory risk is correlated over assets, the spread, depth and other liquidity measures of individual assets would correlate. In terms of another source of liquidity, asymmetric information, Chordia et al insist it should affect the trading within each industry.

In order to examine the commonality of liquidity, in Chordia, Roll and Subrahmanyam (2000), the response of market liquidity to individual asset liquidity is estimated in the cross-sectional models. Furthermore, the commonality of liquidity measure is also test by controlling the trading activity characteristics and liquidity determinants. Note that the variable of liquidity in the regressions is the percentage changes of liquidity measures, either of the individual asset or of the market-wide. The evidence of co-movement of individual liquidity to market is exposed by the regression results - the estimations of slopes of market-wide liquidity are positive and significant. Therefore, the commonality of liquidity is detected accordingly.

Being interested in the covariation of liquidity across-asset, Hasbrouck and Seppi (2001) study the liquidity level instead of working on the change of liquidity as Roll and Subrahmanyam (2000). The data are from NYSE's TAQ database but limited to the 30 Dow Jones stocks. By the examination of the liquidity interaction using two methods - principal component analysis and canonical correlation analysis, Hasbrouck and Seppi (2001) explore whether the covariation of order flow impacts the covariation of return. They find that the two-third commonality of return comes from order flow covariation. The future return proxy variable dominates the common factor of order flow, while firm-specific liquidity covariation dominates the common factor.

Huberman and Halka (2001) investigate the systematic component of the liquidity, of which is measured by four measures, i.e. bid-ask spread, proportional spread (spread/price), depth (averaged number of shares traded at bid/ask price) and dollar depth (number of shares traded times transaction price). The evidence is supported by the positive correlation of liquidity proxies and their unexpected innovations (the variable of residual term in time-series regression), even after controlling the factors which are potentially related to variations. In particular, the variables, which could potentially determine the inventory risk and the asymmetrical information, i.e. market positive return, market negative return, return volatility, interest rate volatility and expected/unexpected trading volume, are considered in the regressions. However, none of them captures the variation of liquidity.

The empirical studies of Chordia, Roll and Subrahmanyam (2000), Hasbrouck and Seppi (2001), and Huberman and Halka (2001) support the existence of the systematic risk of liquidity, which is time-varying persistent but not diversified. Their work links asset pricing to time-varying market-wide liquidity. The existence of commonality of across-asset liquidity in market-wide indicates that the covariance, which is between individual asset's illiquidity and market illiquidity, is positive. Hence, investors are compensated for holding an asset which is illiquid when market becomes illiquid. Acharya and Pedersen (2005) propose and study the theoretical model of liquidity-adjusted CAPM, which introduces systematic liquidity risk variables. More details of this model are explained later in section 2.7.

2.4 Liquidity Risk Premium

Amihud (2002) indicates that there are two ways to study the effect of liquidity on asset returns: the significant estimated coefficients of the illiquidity (as one of stock characteristics) which is regressed on asset returns; the stock's sensitivity to an illiquidity factor, which varies systematically across stocks by their size or liquidity. Amihud (2002) provides evidence of the time-series effect of asset liquidity on returns on market-wide level. The liquidity is decomposed into expected and unexpected terms. In particular, the expected market illiquidity positively affects ex ante stock excess return, while the unexpected market illiquidity affects contemporaneous stock return negatively. On the other hand, the effects of market aggregate illiquidity, both components of expected and unexpected, are stronger for small size stocks than larger firms. Note that the differential sensitivity across smaller and larger assets is due to "flight to liquidity", which suggests that liquid (larger) assets are more attractive than illiquid (smaller) assets. Saying differently, the more sensitive of small assets to market illiquidity, the greater illiquidity risk these assets have, and the higher illiquidity risk premium earned.

Amihud (2002) focuses on the effect of the sensitivity of asset to market-wide liquidity, while Pastor and Stambaugh (2003) investigate that of the fluctuation of market aggregate liquidity. The latter study works on the hypothesis that market-wide liquidity is a state variable for asset pricing. Pastor and Stambaugh (2003) propose "liquidity beta" which indicates the cross-sectional differential sensitivity to the innovations of market-wide aggregate liquidity, and the sensitivities are related to the cross-sectional differences in expected stock returns. In particular, the stocks, which are more sensitive to the innovations of market liquidity, are more exposed to the liquidity risk and command higher expected returns; the assets that have less sensitivity to the liquidity risk, require lower expected return by investors. The empirical analysis is conducted as follows: to sort the stocks into ten portfolios by liquidity beta, which is estimated in the regressions of returns on the Fama-French factors and the liquidity risk, using data of three or five years; within each portfolio, to estimate the alpha under CAPM, Fama-French model and the four-factor model, respectively, as the alpha in the liquidity beta-based portfolios reflects whether the liquidity risk in priced in asset returns; to estimate liquidity risk premium by GMM. The results provide convincing evidence that the aggregate liquidity risk is a state variable for asset pricing, and the asset which is more sensitive to the risk commands higher returns.

Acharya and Pedersen (2005) provide a unified theoretical model which explains how liquidity risk affects asset returns. There are three channels: the commonality of liquidity, which is the systematic component of liquidity across assets, and the co-movement between the individual liquidity and the market-wide liquidity commands compensation for holders, as studied in Chordia, Roll and Subrahmanyam (2000); the sensitivities of asset returns to the changes of market-wide liquidity, to see Pastor and Stambaugh (2003); the covariation between asset liquidity and market return is priced. In addition to the liquidity risk, liquidity level also requires risk premium, according to numerous studies, e.g., Amihud and Mendelson (1986), Brennan, Chordia, and Subrahmanyam (1998), Chordia, Subrahmanyam and Anshuman (2001), etc.. The empirical results support that the three channels through which the liquidity risk contributes to asset returns, at about 1.1% annually to the difference in risk premium between liquid and illiquid stocks. Three components from the above three channels are 0.08%, 0.16% and 0.82%, respectively.

By sorting assets into groups, Acharya and Pedersen (2005) discover three properties of illiquid assets: they have higher commonality in liquidity, as well as higher liquidity sensitivity to market returns, and their returns are more sensitive to the change of market-wide liquidity. Those properties are consistent with the "flight to liquidity" in down market.

The liquidity risk premium is also investigated through mimicking liquidity factors by the long-short strategy in empirical studies, e.g., Sadka (2003), Liu (2006) and Florakis, Gregoriou, and Kostakis (2011). Sadka (2003) decomposes the variable of price impact into the components of transitory variable effect as $\bar{\lambda}$, permanent fixed effect ψ , and permanent variable effect λ ; he constructs the liquidity factors by sorting stocks into portfolios on the basis of $\overline{\lambda}$ or ψ , and taking long position of the most illiquid portfolio and short position of the most liquid one, thus, the returns process of this zero-cost profit returns is taken as the mimicking liquidity factor. The estimation of alpha from Fama-French regression is reduced, more or less, when the liquidity factors are added in the regressions. Liu (2006) proposes an alternative liquidity measure, LMx, the standardized turnover-adjusted number of zero daily volume over the prior x months (x = 1, 6, 12). The failure of CAPM and Fama-French model to explain the liquidity premium using this new liquidity measure, as well as the suggestion that the market aggregate liquidity risk is a state variable by Pastor and Stambaugh (2003) motivates Liu (2006) to study the liquidity-augmented two-factor model. The liquidity factor is constructed by mimicking portfolios, similar to previous asset pricing studies, for instance, Fama and French (1993). Liu sorts all stocks in ascending order based on $LM12$. Two portfolios, low-liquidity (LL) and high-liquidity (HL) are formed, and they are held for 6 months. The liquidity factor is constructed as the monthly profits from buying \$1 of equally weighted LL and selling \$1 of HL. The return spreads between the portfolio with the highest liquidity beta and the portfolio with the lowest liquidity beta are significant. It indicates that the liquidity risk is priced in returns, and investors require higher compensation for the stocks with greater exposure to market liquidity risk. This conclusion is consistence with Pastor and Stambaugh (2003). Florakis, Gregoriou and Kostakis (2011) empirically test the proposed liquidity measure, the ratio of return to turnover rate, by examining the abnormal performance of portfolios, which are constructed based to the liquidity measure. The tests are conducted in three asset pricing models - CAPM, Fama-French model, and Carhart-Four-Factor model. The Jensen alphas in the three asset pricing models are estimated in ranked portfolios. Furthermore, after obtaining the estimation of abnormal returns in portfolios with liquidity risk, Florakis, Gregoriou and Kostakis propose to examine the pricing of liquidity factor in those three pricing models. Provided that the coefficient estimation of liquidity factor is significant and positive, the augmented pricing model is not mis-specified.

2.5 Volatility of Liquidity

Being different from the studies focusing on systematic liquidity risk, for instance Pastor and Stambaugh (2003) and Acharya and Pedersen (2005), a few papers notice that the total volatility of liquidity is also very interesting.

Chordia, Subrahmanyam and Anshuman (2001) follow Brennan, Chordia and Subrahmanyam's (1998) approach to estimate the regression of stock characteristics on cross-sectional asset returns. Provided that liquidity level is significantly priced in asset returns, Chordia, Subrahmanyam and Anshuman (2001) investigate the effect of liquidity variations on expected returns, uncovering the negative slopes of the variability of trading activity when the latter is regressed on asset returns. The negative estimation of slopes is in favor of the presence of lower return of stock are required in heavy fluctuations in liquidity. The significant effect survives from a number of robustness checks after controlling for the level of trading activities, size, book-to-market, price level, and momentum effect. However, this negative relation is opposite to the intuition that investors require higher return to compensate for bearing the liquidity risk, as suggested by Hasbrouk (2006).

Pereira and Zhang (2010) explain the negative relationship between asset returns and volatility of liquidity through a utility-maximizing investment strategy of a rational risk-averse investor, where liquidity is a stochastic price impact process. The risk-averse investor maximizes the wealth utility by taking advantage of the states of liquidity, and, thus, bettering the potential losses due to low liquidity. In other words, the investor trades large volumes in high liquidity states in order to avoid bad liquidity states. Higher liquidity volatility provides more trading opportunities to strategize his trades and results in lower required liquidity premia and expected asset returns. In empirical study, Pereira and Zhang (2010) provide the evidence from the Grange causality results and imply that the larger price impact Grange causes less trading volume or turnover, that is, the trades of investors are adapted based on the liquidity states. Moreover, according to the impulse response function tests, price impact decreases by the positive shock to trading activity, while the latter also decreases by the positive shock to price impact.

Barinov (2011) claims that the negative relationship between volatility of turnover and asset return results from asset idiosyncratic risk, which is positively correlated with turnover variability and aggregate return volatility. Hence, the volatility of turnover is no more than a proxy of aggregate volatility risk, which in turn predicts the asset returns in the negative direction, according to Campbell (1993), Chen (2002) and Ang, Hodrick, Xing, and Zhang (2006).

Barinov (2011) examines the effect of liquidity volatility on asset expected returns, by other liquidity measures. He finds that the relationship between asset returns and liquidity volatility is significant only when the liquidity is measured by turnover rate. However, Blaua and Whitby (2013) provide evidence to support that the liquidity variability affects expected returns positively, when liquidity is measured by bid-ask spreads. They also claim that the liquidity variability is an important component of illiquidity concluded from the asset pricing empirical results.

2.6 Momentum

Momentum is detected by Jegadeesh (1990) regarding the predictability of asset return, which is one-month ahead continuous performance of asset return. Jegadeesh and Titman

(1993) study the momentum effect for the following months, and find that the assets which perform well in the past few months would continue to be winners, while those have low returns tend to perform poorly for the next few months. The response of a piece of new information would only last over a period of time, thus, stock prices will exhibit the positive serial correlation. In addition to the discovery of outperformance of short-term winners, another important indication from their study is that the momentum effect is stronger of losers than of winners. That is due to investors' asymmetric reaction to good news and bad news.

However, in addition to the short-term continuation of portfolio performance, the studies of stocks over periods of several years present an opposite pattern, that is, negative serial correlation of portfolio returns leads the long-term losers to outperform the long-term winners. For instance, Bondt and Thaler (1984) and Poterba, and Summers (1988) investigate the asset long-term reversals and explain this statement by return mean reversals and market overreaction. In particular, the interest rate, which reverses to mean over time, generates the asset return reversals, or mean reversion, in a way that is quite consistent with the efficient functioning of markets. A few researchers such as DeBondt and Thaler (1985) provide convincing evidence of longer-term overreaction.

There is a body of literature studying the momentum. Since this thesis concentrates on liquidity, I focus on the part of literature which is related to the study of liquidity and momentum. For example, Moskowitz and Grinblatt (1999), and Grundy and Martin (2001) point out that the trading strategies, including momentum strategies, involve high turnover which should be considered in empirical studies; eventually, transaction costs and taxes occur during trading could possibly reduce the profits from momentum strategies. Lee and Swaminathan (2000) find that the momentum effect is stronger among high-turnover stocks; besides, not only magnitudes but the persistence of price momentum is predictable by past trading volumes. Glaser and Weber (2003) provide evidence by studying German market that the assets of high-turnover ratio generate higher momentum profits, which are driven by past winners. Those mentioned papers study liquidity and momentum profit, and claim that momentum profits are significantly related to and affected by asset liquidity.

In order to give explanation of momentum anomaly, Sadka (2003) conducts analysis that half of the momentum anomaly is explained by liquidity risk premium and the unexplained part is due to illiquid stocks. Specifically, the estimated alphas from momentum strategies are significantly reduced by half after introducing the liquidity factors into the regression models; in addition, liquidity beta of winners are larger than losers, that is, higher sensitivity of winners to the market-wide liquidity shocks than losers; hence, the momentum continuation is partially explained by a liquidity premium. As for the illiquidity level, it is involved in trading strategies, and may indicate a possibility of limits to arbitrage.

The momentum anomaly is connected to market-wide liquidity in most recent papers. For instance, Chordia, Subrahmanyam, and Tong (2014) connect the momentum anomaly to market liquidity. Their study is based on the intuition that, in liquid market, more arbitrage trading activity reduces asset anomaly, including the momentum payoff, especially after decimalization since 2001 when trading costs are significantly reduced. On the other hand, Avramov, Cheng and Hameed (2015) provide empirical evidence, in their unpublished manuscript, that the payoff of momentum portfolios crucially depends on market illiquidity. They examine the impact of market illiquidity on momentum profit, finding lower momentum profit following illiquid market, and higher momentum portfolio returns after relatively liquid market. The evidence is opposite to Chordia, Subrahmanyam, and Tong's (2014) claim. Avramov, Cheng and Hameed (2015) suggest that their work is consistent with the overconfidence-illiquidity relation, conditional on the statement that market illiquidity is a proxy of absence of overconfident investors, whose reaction causes return continuation. In illiquid market state, the reducing momentum payoff is partially from the market illiquidity and investors' little overconfidence, partially from the deterioration of loser stocks' liquidity, especially the illiquidity effect of losers exceeds the price continuation effect of winners.

2.7 Background Papers and Theoretical Foundation

Amihud and Mendelson (1986) provide the link between market microstructure and asset pricing. Specifically, Amihud and Mendelson (1986) propose that asset expected return is an increasing and concave function of asset relative spread, which is the difference of ask and bid prices divided by prices. In particular, the spread is in fact the sum of buying premium and selling concession. Another proposition in Amihud and Mendelson (1986) is clientele effect: the assets with higher transaction cost are in equilibrium automatically allocated to those investors who prefer longer holding horizons, likewise, the investors with short investment horizons are holding more liquid assets. This thesis briefly summarizes the derivation process of both propositions in Amihud and Mendelson (1986).

The first proposition of the relationship between asset return and spread is derived from a basic idea that the asset return equals to the present value of all future expected dividends minus transaction cost, taking account of expected holding times. First of all, suppose that investors are risk-neutral and the discount rate of assets is $\frac{1}{R^f}$, where $R^f = 1 + r^f$ is the risk-free real return. On the other hand, the revenue of holding a asset should be the expected future dividend, d, plus the future selling price, P, minus the transaction cost, C, that is, $(d + P - C)$, hence, the expected discounted revenue is $\frac{d+P-C}{R^f}$. Considering the case of equilibrium and no-arbitrage, the price should equal to the expected discounted revenue $\frac{d+P-C}{R^f}$. Thus, by $P=\frac{d-C}{R^f}$, it indicates that the price of asset is the present value of future dividends minus the transaction costs. After rearrangement of the equations of asset price and asset return, it is obtained that $E(r)=r^f+\frac{C}{P}$, the required asset return is risk free return plus relative transaction cost, or, $r^f=\frac{d-C}{P}$, the risk free return is the liquidity-adjusted return.

However, for an economy with more than one period, the motivation of each trade could be the need for cash or speculation. Therefore, the expected trading frequency μ, which is reciprocal of holding time T, should also be considered in order to evaluate an asset. Saying differently, the transaction cost is weighted by the expected trading frequency, that is, the expected return of an asset equals to the risk-free rate, plus the relative transaction cost: $E(r_i)=r^f+\frac{\mu C_i}{P_i}$, where μ denotes trading intensity (the reciprocal of holding period T). $\frac{C_i}{P_i}$ is the relative transaction cost. The last term $\frac{\mu C_i}{P_i}$ is per-period percentage transaction cost. The equivalent equation shows that the required return is the risk free return in addition to the per-period percentage transaction cost, which is weighted by the expected trading frequency μ.

The second proposition of Amihud and Mendelson (1986) is the clientele effect. The intuition comes from the various trading frequency or the probability of different types of investors. The investors who trade frequently require higher returns, as compensation for per-period trading costs, than the infrequently-trading investors. Because the latter type of investors can amortize the trading costs over a long holding time. Hence, the assets with higher transaction costs are automatically allocated to those investors who have longer holding horizons.

The liquidity-adjusted return is $\frac{d-\mu C}{P}$, where μ is the probability to liquidate the asset, saying differently, enter or exit the trading, of different types of investors. Thus, type-j investor has an asset of which the price is $\frac{d-\mu^j C}{r^{*j}}$, where r^{*j} is the required liquidity-adjusted return by investor j, so that investors earn higher liquidity-adjusted returns by holding the asset for longer time (or lower possibility μ^j to trade). The difference between the liquidity adjusted return and risk-free rate is the rent by holding the asset, ($r^{*j} - r^f$). Therefore, the equation of the expected asset i return of investor j is $E(r_i) = r^f + (r^{*j} - r^f) + \frac{\mu^j C_i}{P_i}$, where $\frac{\mu^j C_i}{P_i}$ is the amortized relative trading cost, thus, the expected return of asset i is the increasing and concave function of the relative trading cost $\frac{C_i}{P_i}$.

Being apart from proposing the illiquidity measure (return to dollar volume), Amihud (2002) examines the effect of illiquidity on asset return, both on market-wide and across-portfolios. Amihud (2002) hypothesizes that ex ante stock excess return is an increasing function of expected illiquidity, and, on the other hand, the component of unexpected illiquidity has a negative effect on contemporaneous unexpected stock return. He employs data of NYSE stocks during 1964–1997, and follows the approach of French (1987) to conduct this empirical study. In particular, the expected illiquidity is estimated by an autoregressive model, and the unexpected component is the residual variable from the autoregressive regression.

Market illiquidity is measured by averaging the individual stocks' annual illiquidity across market, denoted by $AILLIQ$. Since the illiquidity is persistent in time-series dimension, the autoregressive model is:

$$\ln AILLIQ_t = \beta_0 + \beta_1 \ln AILLIQ_{t-1} + \varepsilon_t \tag{2.20}$$

$$\ln AILLIQ_t^E = \beta_0 + \beta_1 \ln AILLIQ_{t-1} \tag{2.21}$$

where $AILLIQ_t^E$ is the expected average illiquidity, ε_t is the unexpected component of market illiquidity of year t.

Thus, the excess return of market portfolio of year t, could be modeled by the variables of expected and unexpected market illiquidity:

$$R^{mkt}{}_t = a_0 + a_1 \ln AILLIQ_t^E + a_2 \ln AILLIQ_t^U + \xi_t \tag{2.22}$$

or

$$R^{mkt}{}_t = b_0 + b_1 \ln AILLIQ_{t-1} + b_2 \ln AILLIQ_t^U + \xi_t \tag{2.23}$$

where the unexpected market illiquidity, $\ln AILLIQ_t^U = \varepsilon_t$, is estimated from the above equations.

The hypothesis is that higher expected market illiquidity leads to higher ex ante stock excess return, that is, the estimation of b1>0. In addition, the unexpected market illiquidity negatively impacts the contemporaneous stock returns, or b2<0. The former is consistent with the theory that investors may require higher compensation for holding illiquid assets. However, on the other hand, the increasing expected illiquidity raises following stock returns, that is, the contemporaneous stock prices are lowered. Hence, the unexpected component of market illiquidity is negatively related to the contemporaneous stock prices and returns.

Moreover, the effect of the expected and unexpected illiquidity on market return also applies on portfolios. Amihud (2002) examines size-sorted portfolios, and conducts the regressions of the market illiquidity variables on returns of each portfolio. The estimation results are significant - the coefficients of b1 are positive and declining in size, while the coefficients of b2 are negative and increasing in size. The results suggest that the smallest firms are stronger affected than the largest firms by the market illiquidity, either the expected or the unexpected components. In other words, when the market illiquidity increases, the smaller firms are more affected than the larger firms; when the unexpected illiquidity rises up, the contemporaneous returns of smaller firms are increasing more than big stocks. Note that the sensitivity varying across smaller and larger assets due to the effect of "flight to liquidity", which suggests that the liquid (larger) assets are more attractive than the illiquid (smaller) assets.

Acharya and Pedersen (2005) propose a dynamic OLG model which is regrading the liquidity effect on asset returns. The liquidity-adjusted asset pricing model shows that liquidity risk could be decomposed into three components, and displays the channels of those liquidity risk components to affect the expected returns. In particular, the three components are the commonality of liquidity, the covariance between the asset returns and the market liquidity, and the covariance between the asset liquidity and market return.

The motivation of Acharya and Pedersen (2005) is from how the asset illiquidity, the market returns, and market illiquidity affect the asset's expected gross returns. Intuitionally, the net return of a single asset should be related to the market net return, where the "net" indicates the reduction of transactions costs such as broker fees and bid-ask spread:

$$E_t(r_{t+1}^i - c_{t+1}^i) = r^f + \beta * E_t(r_{t+1}^m - c_{t+1}^m - r^f) \tag{2.24}$$

where r_{t+1}^{i} is the return of asset i, r_{t+1}^{m} is the market return, r^{f} is the risk free rate; c_{t+1}^{i} is relative transaction cost of asset i, c_{t+1}^{m} is the relative market-wide transaction cost. $E_t(r_{t+1}^{m}-c_{t+1}^{m}-r^{f})$ is the risk premium, and β is the sensitivity of the asset net return to the market net risk premium. Mathematically, the beta could be expressed as follows:

$$\beta_t=\frac{\text{cov}_t(r_{t+1}^{i}-c_{t+1}^{i},r_{t+1}^{m}-c_{t+1}^{m})}{\text{var}_t(r_{t+1}^{m}-c_{t+1}^{m})}+\frac{\text{cov}_t(c_{t-1}^{i},c_{t+1}^{m})}{\text{var}_t(r_{t+1}^{i}-c_{t+1}^{m})}-\frac{\text{cov}_t(r_{t+1}^{i},c_{t+1}^{m})}{\text{var}_t(r_{t+1}^{m}-c_{t+1}^{m})}-\frac{\text{cov}_t(c_{t+1}^{i},r_{t+1}^{m})}{\text{var}_t(r_{t+1}^{m}-c_{t+1}^{m})}$$

(2.25)

The first component $\beta_t^{MKT}=\frac{\text{cov}_t(r_{t+1}^{i}-c_{t+1}^{i},r_{t+1}^{m}-c_{t+1}^{m})}{\text{var}_t(r_{t+1}^{m}-c_{t+1}^{m})}$ is actually the market beta, which captures the covariance between the asset net return and the market net return.

The second beta $\beta^{L1}=\frac{\text{cov}_t(c_{t-1}^{i},c_{t+1}^{m})}{\text{var}_t(r_{t+1}^{i}-c_{t+1}^{m})}$ is the sensitivity of the asset liquidity to the change of market-wide liquidity, namely, it reflects the commonality of across-asset liquidity; positive sign indicates that asset expected return increases with the covariance between asset's illiquidity and market illiquidity, because of the compensation required by the investors in order to hold the illiquid assets. Note that these illiquid assets tend to be even more illiquid when the market is in general illiquid.

The third beta $\beta^{L2}=\frac{\text{cov}_t(r_{t+1}^{i},c_{t+1}^{m})}{\text{var}_t(r_{t+1}^{m}-c_{t+1}^{m})}$ reflects the comovment of asset return to the market-wide liquidity. Providing that the increasing market-wide illiquidity reduces asset values, the more exposure of asset return to market illiquidity, the lower asset return is expected by investors.

The last beta $\beta^{L3}=\frac{\text{cov}_t(c_{t+1}^{i},r_{t+1}^{m})}{\text{var}_t(r_{t+1}^{m}-c_{t+1}^{m})}$ is the covariation between asset liquidity and market return. It indicates the sensitivity to security's illiquidity to market conditions. In adverse market, when the market declines, the investors tend to value the easiness to trade their holding assets, or the liquidity of assets. Hence, the asset of which the illiquidity is more sensitive to market return, for instance, a stock which becomes more illiquid when the market is down, and is usually not preferred by investors, unless required the compensation to expected returns.

The empirical results support that the three channels through which the liquidity risk contributes on asset returns, at about 1.1% annually to the difference in risk premium between liquid and illiquid stocks. Three components from the above three channels are 0.08%, 0.16% and 0.82%, respectively.

Chapter 3

A Comparative Analysis of the Liquidity Measures: Evidence from Time-series and Cross-sectional Effect

Abstract

Liquidity has played a pivotal role in predicting transactions from both the theoretical and practical standpoint. Due to the intrinsic complexity of liquidity, researchers have come up with numerous ways of measuring liquidity. However, a unanimous agreement on the precise quantification of liquidity remains elusive, especially in terms of the effect of individual asset liquidity on its return. To mitigate the chaos in selecting different liquidity measures in different situations, this thesis aims to quantify the liquidity in a comparative framework and implement an extensive analysis on how liquidity affects stock returns. I conduct two analyses to exploit the inter-relationship between different liquidity measures: cross-sectional regression and time-series method, using data of the common shares listed in NYSE-AMEX. In the first approach, I investigate the impact of illiquidity level on individual asset returns. It conducts a cross-sectional regression through Fama-MacBeth method with whole sample as well as sub-period samples, to quantify and compare the

performance of different liquidity measures. Techniques enable us to identify interesting patterns along two dimensions: 1) Across liquidity measures, certain liquidity measures work in the line with liquidity theory in certain sub-periods, while other measures have different behaviour under different periods, suggesting that more robust liquidity measures can be derived from our analysis. 2) Across Business Cycles, the effect of liquidity on stock return differs within certain sub-periods. Most interestingly, it is investigated that financial crises usually yields high liquidity premium. In the second approach, I investigate the bidirectional Granger causality between certain categories of liquidity dimensions as well as between liquidity dimensions and market variables. By the causality, one is able to detect the interaction of the market information and liquidity dimensions. These observations for liquidity measures in this comparative analysis establish a significant step towards the understanding of liquidity measures in a more systematic and consistent setting, and can be a good starting point for constructing more robust liquidity measures.

3.1 Introduction

The easiness to buy and sell stocks bears no clear cut role on expected stock returns. Theoretical and empirical models adhere to two separate schools, one set out by Amihud and Mendelson (1986) advocating that increased illiquidity commands higher returns and another by Constantinides (1986) claiming that transaction costs do not affect asset pricing. This chapter aims to contribute to this discussion by investigating the pricing of stock liquidity's effect. Six established liquidity proxies spanning three categories of liquidity dimensions, namely - transaction costs, trading activity, and price impact are employed.

According to the first component of liquidity, stock return is an increasing and concave function of transaction cost and thus investors require higher returns for holding illiquid assets. Likewise, according to the trading activity component, investors' holding period is positively associated with transaction cost and consequently affects liquidity. Finally, the price impact accounts for the price response to order flow.

The objective of this chapter is to investigate empirically the liquidity effect on the risk-return trade-off. The aim is implemented through the investigation of the liquidity premium dynamics on an asset pricing framework. Specifically, the aim is to quantify the liquidity risk premium comparatively with respect to its main dimensions and to investigate further its time dynamics. I further consider the liquidity measures on a market-wide level and analyse their causality with aggregated market characteristics. In the time-series dimension, the VAR is employ to conduct the Granger causality tests. The findings suggest that there exists a heterogeneity in terms of the liquidity constitutes which is time specific, though during non-tranquil periods illiquidity yields high returns. Moreover, it is found that the bidirectional causal relationships between liquidity and market characteristics according to Gervais, Kaniel, and Mingelgrin (2001).

3.1.1 Motivation

The influence as a strong suggestive indicator of liquidity in transactions has been well-established from both theoretical standpoint and practical standpoint. A higher tendency for transactions is commonly observed when the liquidity is higher. Based on the assumption that the liquidity states determine the trading timing for investors, Pereira and Zhang (2010) investigate the strategies of maximizing the investors' utility in an equilibrium model. Investors prefer trading on more liquid days; otherwise, higher return is required as compensation for illiquidity, as a result of lower asset prices in the state of low liquidity, which is less favourable for investors. The hypothesis that the heavier trading happens in higher liquidity conditions in market has been confirmed by empirical results of Granger causality tests of market-wide trading activity (presented by dollar trading volume and turnover ratio) and liquidity (measured by Amihud's (2002) R/DVOL ratio). This argument is addressed by Chordia, Roll, and Subrahmanyam (2001) who claim that liquidity effect is self-perpetuating, and in particular, agents tend to abate or even refrain from further trading after noticing a liquidity anomaly, which, in turn intensifies the anomaly by further reducing liquidity in those periods.

Due to the importance of liquidity in indicating transactions, there is a rich literature on the study of liquidity, and any quantitative research has to rely on a good measure of liquidity. A common agreement is that only transactions data are not sufficient, and other factors deserve being taken into account. Among the determinants of liquidity, the most significant ones are inventory risk and asymmetric information (see Brennan and Subrahmanyam (1996)). According to Chordia, Roll and Subrahmanyam (2001), inventory risk affects the incentive to trade and determines the market depth, hence one of the most essential indicators of market liquidity. On the other hand, information is biased in investors, and informed speculator and liquidity-motivated investors have differential access to private information. In particular, with narrow spread against speculator, the market maker feel less secure and thus are reluctant to enter transactions, hence enlarging spreads and reducing liquidity.

However, the concept of liquidity in financial market is intrinsically complicated (Amihud, Mendelson, and Pedersen (2005)), and without a definitive quantitative definition, one could not hope to measure the liquidity directly. Since the liquidity is commonly reflected on the easiness that an asset is traded at low transaction cost with little price impact, the aspects include trading quantity, trading speed, trading cost and price impact. In this respect, previous measurement considered in literature includes the bid-ask spread of Amihud and Mendelson (1986), the turnover ratio of Datar, Naik, and Radcliffe (1998), the dollar trading volume of Brennan, Chordia, and Subrahmanyam (1998), the return to dollar volume ratio of Amihud (2002) and the return to turnover ratio of Florakis, Gregoriou and Kostakis (2011), etc.

Based on their implications for stock return, the aforementioned measurement can be classified into three categories: transaction cost (absolute spread, relative spread), trading activity (turnover ratio and dollar volume) and price impact (return to dollar volume, return to turnover ratio). For instance, according to the spread (S) and relative bid-ask spread (RS), stock return is an increasing and concave function of spread and thus investors who are holding illiquid assets require higher return as compensation. Likewise, according to the turnover ratio (TR), investors' holding period is positively associated with spread and consequently affects liquidity. Furthermore, it is argued that the dollar trading volume (DVOL) captures better liquidity than the bid-ask spread while it is easier to calculate this measure on a monthly basis since the corresponding datasets cover a big number of firms for a long time period. The daily ratio of absolute stock return to its dollar volume (R/DVOL) measures the price impact by order flow, in the sense that it represents the price response to order flow. Finally, the return to turnover ratio (R/TR) is an alternative to the return to dollar volume price impact ratio in order to insulate the size effect and include the trading frequency.

Empirical evidence of the relevant literature involves heterogeneity between the liquidity constituents that varies through time. Even after extensive studies on the measurement of liquidity, a unanimous agreement remains elusive on how to accurately measure liquidity, especially in terms of the effect of individual asset liquidity on its return. For instance, one of the measures, dollar volume, is positively related with liquidity, and should have negative relationship with asset returns according to the liquidity theory, the empirical work could be found in Brennan, Chordia, and Subrahmanyam (1998) and other related papers. However, it is still far from a unanimous agreement, as the opposite opinion is also taken in literature. For example, Gervais, Kaniel, and Mingelgrin (2001) find that share prices tend to increase (decrease) over the subsequent days due to unanticipated high (low) past volume. They claim that the high trading activity could be the signal of information or attention instead, resulting in high return. Both of the above-mentioned hypotheses are reasonable and in line with theory, but, none of them would account adequately for the risk-return trade-off. A comprehensive empirical analysis would potentially enlighten the investigation of liquidity effect across its dimensions.

In order to have a more comprehensive picture of the impacts of major liquidity measures on returns, this chapter implements a systematic empirical study and unified comparative analysis. This analysis suggests that, under this more comprehensive view, some seemingly contradictory conclusions reported previously might be conciliated. In particular, I examine the impact of liquidity on asset returns by cross-section tests over whole time horizon, i.e., from 1961 to 2011; in addition, the experiments are conducted in sub-periods, for the purpose of verifying the relationship between liquidity measures and asset returns. In this study, the sub-periods are selected as eight business cycles. Typically, the business cycle is the downward and upward movement of gross domestic product (GDP) around its long-term growth trend, and a type of fluctuation found in the aggregate economic activity. In the Keynesian view, business cycles reflect the economy may reach short-run equilibrium. In other words, selecting business cycles as sub-periods study regarding the significance of liquidity on asset return, is mainly because that within each business cycle there is a whole session of upward and downward of economy trend, thus, considering that real economy is closed related to stock market and its liquidity, it is reasonable to implement the test over long term as well as in each single business cycle. On the other hand, a business cycle consists of an expansion and a recession; the expansion is the default mode of the economy, with "recession can extract a tremendous toll on stock markets". It is common observation that, in recessions, the market liquidity is low relative to expansion periods. Besides, liquidity premium itself could also vary over expansions and recessions[3]. From this aspect, it is reasonable to select business cycles as sub-periods in examinations, since in each sub-period, there are two diverse states regarding the liquidity as well as its premium, and allocating the two states (an expansion and a recession) in one horizon of examination is fair practice for comparison reason, since it helps to avoid differential liquidity effect in recessions and expansions, and guarantees fair comparison among business cycles.

Moreover, during the examination of possible market-wide interdependencies among those measures, it is observed that the bidirectional Granger causality is between certain categories of constituents as well as between them and market characteristic variables, e.g., market conditions of directions and volatility, and past cumulative returns which stand for the momentum information. In particular, the Granger causality results comprise as a subset of the causality of market conditions by liquidity dimensions, and it partially addresses the concerns posed by Gervais, Kaniel, and Mingelgrin (2001).

Overall, the empirical evaluations for liquidity measures in this comparative analysis provide further insights as to how liquidity influences the transaction in practice, as well as a deeper understanding of the previously developed liquidity measures in a more systematic and consistent setting. As suggested by our empirical results, our research establishes a significant step towards the understanding of liquidity measures, and can be a good starting point for constructing more accurate liquidity measures.

3.1.2 Objective

[3] As discussed in Næs, Skjeltorp and Ødegaard (2011), asset liquidity incorporates information which is related to real economy, and even useful to predict GDP growth, unemployment and investment growth. The consideration is based on the fact that in recession or crisis period, a phenomenon of flight-to-liquidity occurs and liquid investment pervades, thus, those illiquid assets in illiquid states or recession periods shall require higher premium as compensation.

The objective of this chapter is to investigate the majority liquidity measures in terms of the effect on asset returns. In order to derive any meaningful judgment with a high level of confidence from the liquidity measures, it is necessary to exploit the correlation between returns and other pricing factors, such as non-risk firm characteristics and macroeconomics variables to reflect the market conditions, in a unified setting. The comparative study should consider all these factors synergistically to balance out possible bias in previous works, and can be served as a reference for market participants, individual and institutional investors, and market makers in their analysis work.

Specifically, I conduct two approaches to exploit the inter-relationship between different liquidity measures.

1. Cross-sectional regression. In order to investigate the impact of illiquidity level on individual asset returns, I conduct a cross-sectional regression through the Fama-MacBeth method with whole sample as well as sub-period samples, to quantify and compare the performance of different liquidity measures. The regression considers several firm fundamental characteristics and momentum proxies in a comparative framework (with six liquidity measures included). The technique enables us to identify interesting patterns along two dimensions: 1) Across liquidity measures, certain liquidity measures work in the light of liquidity theory in certain sub-periods, while other measures have different patterns of behaviours in different periods. The implication of these perturbations can lead to the development of a more robust liquidity measure. 2) Across Business Cycles, the effect of liquidity on stock return differs within certain sub-periods. Most interestingly, it is estimated that financial crises usually yields high liquidity premium.

2. Time-series VAR model. I examine the time-series Granger causality from the liquidity measures (transaction cost, trading activity, and price impact) to market conditions (negative return, positive return, momentum proxies, market volatility) via VAR estimation.

This model enables us to detect the bidirectional Granger causality between certain categories of dimensions as well as between them and market variables, e.g., market conditions of directions and volatility, and past cumulative returns to proxy the momentum information. Complementary to the cross-sectional tests which investigate the individual asset liquidity and return, the time-series test in this chapter consider the liquidity and information (market conditions) at market level. In this case, one is able to explore the inter-relationship not only between different liquidity measures, but between the liquidity measures (in different dimensions) and market condition proxies which contain the information.

3.1.3 Financial Consideration

Liquidity is a crucial attribute of financial assets. The investors are supposed to take liquidity into account for trading decisions, because one has to consider not only the liquidity characteristics to look for trading opportunities, but also the risk, which arises from liquidity, to determine the required returns.

This chapter explains liquidity as the ability to trade a certain quantity of assets quickly, with minimal price impact and trading cost. A liquid investment is one where the participant can unwind the position easily and quickly, without affecting asset prices.

The cost of illiquidity and the exposure to the liquidity risk render risk-averse investors require compensation for bearing the cost or risk. Thus, the illiquidity affects the asset return via investors. For instance, an individual's decision to sell a holding of very active, i.e. liquid, stocks may not produce large impact on the selling price, that is, the liquidity premium is negligible; by contrast, an investor, who is holding a stock which attracts very few market participants, bears uncertainty about price changes and trading timing, consequently, he may sell the asset at lower price than his expectation, and require liquidity premium as compensation to bear the liquidity risk. Constantinides (1986) defines the liquidity premium as the compensation for investors so that he is indifferent between a perfect liquid asset and an asset with certain liquidity risk.

Among the determinants of liquidity special emphasis is given on inventory risk and information (see Brennan and Subrahmanyam (1996)). According to Chordia, Roll and Subrahmanyam (2001), inventory risk affects the incentive to trading and determines the market depth, hence one of the most essential indicators of market liquidity. On the other hand, if informed speculators and liquidity-motivated investors have differential access to private information, then information is not uniformly distributed to all investors. In particular, adjustments on spreads against speculators would potentially diminish trading activity and consequently the liquidity.

Considering the impact of information on transactions, the liquidity provider makes profit from uninformed investor and loses money to informed investor. The uninformed investor is motivated by exogenous demand, while the informed investor is motivated by the private information advantage. The classic adverse selection theory claims that the market maker determines the ask or bid price by observing the market whether the informed trader has arrived. The bid-ask spread increases in the likelihood of an informed trader, in order that the market maker can protect from the loss to the counterpart.

The essay is organized as following: Section 2 survey the literature and explain the liquidity measures I mainly study; Section 3 describe the data and construct the variables for tests, including market-wide indicators at a daily basis, and monthly liquidity measures as well controlling variables for the cross-sectional regressions; Section 4 explains the research methodology and statistic models; the empirical results are described and analysed in Section 5; the final section is Conclusion.

3.2 Literature Review

3.2.1 Spread

The transaction cost component of liquidity contains the (relative) bid-ask spread. According to this liquidity metric high (relative) bid-ask spread is associated with high illiquidity and long holding period of investments. Consequently, investors would require compensation for securities with high bid-ask spread and this would result in high (expected) returns.

Specifically, Amihud and Mendelson (1986) claim that risk-neutral investors buy assets and sell them later in a premium which represents the trading cost and is absorbed in the transaction prices. Thus, the price discount would be the present value of the transaction costs:

$$E(r^i) = r^f + \mu \frac{C^i}{P^i} \qquad (3.1)$$

where $E(r^i)$ is the expected return of asset i, r^f is the risk-free rate to proxy the perfect liquid asset return, μ is trading intensity (which is related to the reciprocal of holding period) and $\frac{C^i}{P^i}$ is the relative transaction cost. The last term $\mu \frac{C^i}{P^i}$ is per-period percentage transaction cost. Amihud and Mendelson (1986) employ relative spread (dollar bid-ask spread to transaction price) to proxy the relative transaction cost $\frac{C^i}{P^i}$ and found that the expected return is an increasing function of the spread. Glosten and Harris (1988) studied the market microstructure and trading mechanism, where the market maker loses money from informed investors and earn money from uninformed ones. Thus, the higher possibility of trading with informed trader, the higher bid-ask spread should be set by market makers, that is, the liquidity is lower. Specifically, market makers submit the order by observing and learning from the market data to determine whether informed traders are involved in the market. The market marker submits an order to sell at ask price and an order to buy at bid price. However, due to the effect of adverse selection, the bid price is discounted because the selling order constitutes bad news to the uninformed market participants, similarly, a premium is added to the ask price as a result of the good news signal brought by the buy order. The difference between the discounted bid price and the raised ask price is the bid-ask spread. As a result, higher spreads are imposed in order to offset potential losses from informed investors. Moreover, while the bid-ask spread provides a mean for reducing the losses or increasing the profits for the market maker who is dealing with informed and un-informed investors, respectively, in the same time it might advocate to the opposite direction by dampening the trading activity of informed market participants or by eliminating the marginal benefit for market makers. It is obvious then, that the trade-off between these opposite effects that the increments of the bid-ask spreads cause, would consequently lead market makers to formulate optimum choices regarding the premiums and the corresponding discounts that should be imposed in the trading mechanism. Hence, spread is a measure of liquidity, not only to proxy the transaction cost, but also reflect the (the degree of) asymmetric information.

3.2.2 Turnover Ratio

The next important liquidity component is the trading activity. According to this liquidity metric low turnover ratio is associated with long holding periods of investments and high spread. Consequently, investors would require a compensation for securities with low turnover ratio and this would result in high (expected) returns.

Amihud and Mendelson (1986) argued that less liquid assets are allocated to investors with longer investment horizons. In addition, Atkins and Dyl (1994) found a positive relationship between the average holding horizon and the spread. Since turnover ratio is the reciprocal of average holding period and is related to how quickly a dealer expects to turn around his position, the turnover ratio (trading volume divided by share of outstanding) is also used as one of the liquidity measures.

Prior studies of the liquidity employ turnover ratio as proxy. Datar, Naik and Radcliff (1998), Rouwenhorst (1999) and Nguyen, Mishra, Prakash and Ghosh (2007) use turnover ratio to measure liquidity: their motivation to employ turnover ratio as liquidity proxy is that low turnover ratio implies long holding horizon and large spread, thus, lower turnover ratio indicates lower liquidity. Datar et al (1998) predicts that the lower turnover ratio, the higher expected return. They perform the cross-sectional regressions, in which the dependent variable is excess stock return (NYSE, 1963-1991), while right-hand variables are beta, firm size, B/M ratio and turnover ratio. The average of time-series coefficients of the turnover ratio is negative and significant. Nguyen et al (2007) also find significant effect of liquidity on return when they use turnover ratio as liquidity measure and test on Fama-French (1993) factors when they sort stocks into 25 portfolios based on size, book-to-market ratio and liquidity, moreover, this effect is significant in a cross-sectional approach of Fama-Macbeth (1973), since the turnover ratio has significant and negative coefficient on the risk-adjusted return. However, the finding in Rouwenhorst (1999) is different, using 20 emerging market data: the return of the stocks between the high and low turnover ratio is not significantly different, while small and high-beta stocks have higher turnover ratio.

Moreover, there are some extended studies on the interaction between turnover ratio and stock returns. Conrad, Allaudeen, and Cathy (1994) argue that the high-turnover-ratio stocks experience short-term return reversal in the following week, while low-turnover ratio firms experience return continuations. Lee and Swaminathan (1998) found the price momentum effect is stronger in high-turnover-ratio stocks than in low-turnover-ratio stocks in intermediate terms. Brown, Crocker, and Foerster (2009) concluded in a positive relationship between the turnover ratio and return existing in relative large capitalisation stocks (liquid), but it is affected by the market conditions (bull or bear), and they also conjecture that the liquidity effect might be dominated by information or momentum effect. All these findings exemplified above are not able to be explained by the liquidity theory, unless the turnover ratio is positively associated with illiquidity. The latter is implied by Stoll (1978), which uses turnover ratio as adverse information proxy. The intuition is that the private information would lead higher level of trading relative to the outstanding shares. Thus, higher level of turnover ratio indicates the adverse information, which results in the higher spread and higher illiquidity.

3.2.3 Dollar Trading Volume

Another liquidity measure that accounts for the trading activity is the dollar trading volume which is defined as the product of the total number of shares traded by the average price per share. It was firstly studied by Stoll (1978) and it is supposed to be the most important determinant of the bid-ask spread. The bid-ask spread serves as the proxy of transaction cost, of which three components are inventory cost, order processing cost and adverse selection cost. Stoll (1978) considered the inventory cost or holding cost of stocks as a function of holding period, in turn, the holding period is function of trading volume since it is easy for traders to reverse the position if the asset is being heavily traded. Thus, the spread is negatively related to dollar volume. Moreover, Glosten and Harris (1988) provide the evidence that the adverse selection cost is the significant component of bid-ask spread, as well as trading size (order flow) is inversely related to spread. Furthermore, Brennan and Subrahmanyam (1995) estimate the transitory and permanent components of transaction cost as the illiquidity measures and they claim that the trading volume is a primary determinant of the adverse selection cost of transaction. Dollar volume measures the speed of transaction to unwind the position. In particular, low dollar volume in specific transaction indicates illiquidity, since the position could be difficult to get out of and the trading opportunities are fewer than high dollar volume case; likewise, the high dollar volume implies high liquidity. Higher volume typically results in narrower spreads, less slippage (slippage is the difference between the last trade price and the price realized by the next order), and less volatility, according to Chordia, Roll and Subrahmanyam (2000), who document a strong cross-sectional relationship between dollar volume and various measures of the bid-ask spread and market depth. Numerous researchers work on the dollar volume, served as the proxy of liquidity. Brennan, Chordia, and Subrahmanyam (1998) examine a multi-factor asset pricing model where one of the stock characteristics is liquidity level, measured by dollar volume. In their study, the dependent variable is the excess return (1966-1995) of individual stocks, while the right-hand variables are the stock characteristics, including size, B/M, price, and dollar volume. They find the dollar volume and stock expected return has negative relationship. Chordia, Subrahmanyam and Anshuman (2001) document the significant and negative relationship between the return and the dollar volume, as well as the negative relation between return and second moment of dollar volume (the unconditional realized and the conditional GARCH type volatility the standard deviation of past 36 month dollar volume or conditional volatility calculated by GARCH). The response variables in the empirical tests are stock excess returns and FF risk-adjusted returns, respectively, and produce similar estimation of coefficients. The abovementioned negative relation between returns and dollar volume is considered in a cross-sectional dimension. However, in the time-series dimension, Gervais, Kaniel, and Mingelgrin (2001) find a short-term (1, 10, 20 days) positive relation between stock return and dollar volume exploiting further the short and long term dynamics of liquidity. They claim that higher trading activity attracts more investors causing higher prices due to greater demand in the subsequent days.

3.2.4 Return to Dollar Volume

The above liquidity measures reflect the dimensions of transaction cost or trading activity, while another dimension is the price impact of liquidity that is, "trading without changing the price". The first proposed measure is Aminvest ratio: dollar volume / absolute return. This ratio is a measure of how much dollar volume is required to move a stock's price up or down by one percentage point A high ratio means that large amounts of stock can be traded with little effect on prices, thus, the stock is very liquid. The Aminvest measure is very popular among professional investors.

In more recent literature, researchers use the price impact as liquidity measures. Amihud (2002) proposes the ratio of absolute return to the dollar volume, in the inspiration of Kyle (1985) who investigates the price change per unit of the net order flow in stock market, and the results in Kyle (1985) suggest that the impact increases with the asymmetry information and decreases with uninformed order flow. Hence, the measure of return to dollar volume is an alternative expression of the price impact. In particular, this measure indicates the average daily price change to $1 trading volume for individual stocks, where the extremely liquid stocks should be able to absorb more trading volume without corresponding price movements; likewise, substantial response of price to each transaction implies this stock is less liquid in the cross-section dimension. Thus, this measure thus proxies for the illiquidity of a stock.

Amihud (2002) regresses individual stocks' cross-section excess return on this proxy of illiquidity and other stock characteristics (size, divided, past return, standard deviation of daily return), and he finds the positive relation between the return and R/Dvol ratio. In addition, in the time-series dimension, the size-based portfolio with smaller size stocks has stronger return-illiquidity relation than the one with bigger stocks. The similar findings are provided in many other studies.

An extension of Amihud (2002) measure touches to the effect of market situation. Kyle (1985) assumes a symmetric relation between stock price changes and order flows, however, Brennan, Huh, Subrahmanyam (2012) suggest the relation should be asymmetric in up market and down market. In specific, the Amihud (2002) measure is decomposed into elements corresponding to positive and negative return days and empirically convinces that the element associated with down days is strongly priced in the cross-section of stock returns, while the coefficient of the element that corresponds to up days is small and statistically insignificant.

3.2.5 Return to Turnover Ratio

Florakis, Gregoriou, and Kostakis (2011) suggest that the Amihud measure has strong size-bias, because of the fact that the higher volume traded in bigger stocks and forcing conclude that the bigger stocks are more illiquid. Moreover, The Amihud measure ignores the importance of trading frequency, which also determines the required liquidity premium according to the theoretical model of equation (1) in Amihud and Mendelson (1986). It is claimed that the effect of trading frequency dominates the transaction cost.

Hence, Florakis, Gregoriou, and Kostakis (2011) propose to use the ratio of absolute return to turnover ratio, with regard that the turnover ratio has no bias of size effect, and convenient to compare among different markets with different monetary currencies.

Florakis, Gregoriou, and Kostakis (2011) rank the stocks based on the price impact ratios, R/Dvol or R/TR, respectively. They observe that the stocks with higher R/Dvol ratio yield higher time-series average return relative to those with lower ratio. However, this pattern disappear once the market capitalisation factor is considered, that is, the stocks with higher R/TR ratio have lower expected return than the ones with lower ratio.

3.3 Data

The data are collected from CRSP and COMPUSTAT tape. The firms are common securities listed in NYSE-AMEX, providing closing price, bid price, ask price, trading volume, share of outstanding, return at daily frequency, and book value, earning per share, dividend yield. The bid/ask prices are only available after 1990 in CRSP data file. The dataset of other variables ranges from Jan., 1962 to Dec., 2011[4]. The risk free rate is represented by the one-month T-bill rate in US market. The Fama-French pricing factors are downloaded from French library website[5].

The data are filtered excluding:

[4] In this study, the dataset stops at 2011 and its influence will be discussed in later session.

[5] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

- shares that are traded at Nasdaq[6];
- shares that are not available in either CRSP or COMPUSTAT tape;
- the first and last trading month for each firm;
- shares that have fewer than two years prices or fewer than 15 trading days in one month;
- shares with extreme ask/bid prices (less than $5 or larger than $1000, or the closing bid prices are higher than ask prices);
- shares with negative BM values and those which are in the financial services sector;
- shares with extreme dollar market capitalisation, B/M, DY, and EP (less than 0.5% or lager than 99.5% percentile).

Applying these filters to our dataset leaves us with 2050 firms in a month on average, with a minimum of 745 and a maximum of 3154.

Since our empirical investigations are in and 1) cross-sectional scale 2) time-series dimension. Before the tests, I construct the variables by the dataset.

3.3.1 Variables in Cross-sectional Dimension

I am interested in taking cross-sectional investigation of monthly liquidity measures of individual assets, trying to compare the performance of liquidity measures on asset returns. The daily data from CRSP are transformed into monthly security characteristics variables by averaging or summing, in order to obtain the stocks monthly return, monthly closing /

[6] The analysis is restricted to NYSE and AMEX stocks only, due to two main reasons. One is that the volume in Nasdaq stocks are overstated compared with NYSE-AMEX stocks, since inter-dealer trading is included on Nasdaq; the other is the unavailability of trading volume for Nadaq stocks on CRSP before 1982. For simplicity, this study considers NYSE-AMEX only. The similar method applies in BCS (1998) and CSA (2001).

bid / ask prices, trading volume, shares of outstanding, and market capitalization. Note that the daily bid/ask prices are only available after 1990. Moreover, for the sake of considering the momentum effect of asset return, three variables are introduced: RET_{23}, RET_{46} and RET_{712}, as the cumulative asset return from the last three to last two months, from last six to four months, from last twelve to seven months, respectively. On the other hand, the annual data collected from COMPUSTAT are transformed into monthly fundamental data. The dividend yield (DY) is measured by the sum of all dividends paid over the previous 12 months, divided by the share price at the end of the second to last month (Price-end). Comparatively, it is also for book-to-market value (B/M) and earnings-price ratio (EP).

Moreover, based on the daily liquidity measures, I construct the monthly liquidity measures. Note that I remove the outliers (bottom and top 0.5%) of each daily liquidity measures before constructing the monthly liquidity measures. In the below equations, i denotes each single asset, t for day, m for month, n is the number of available trading days in each month.

1) DVOL: the sum of the daily dollar volume, over month m, is the monthly dollar volume for a stock.

$$DVOL_{i,m} = \sum_{t=1}^{n} DVOL_{i,t} \tag{3.2}$$

2) S: the daily absolute spread is calculated as the difference between bid price and ask price. For a single stock, its monthly spread is calculated by averaging the daily spread over the month.

$$S_{i,m} = \frac{1}{n}\sum_{t=1}^{n}(ask_{i,t} - bid_{i.t}) \tag{3.3}$$

3) RS: the daily relative spread is calculated as $RS = \frac{bid - ask}{price}$. For a single stock, its monthly spread is calculated by averaging the daily spread over the month.

$$RS_{i,m} = \frac{1}{n}\sum_{t=1}^{n}\frac{ask_{i,t} - bid_{i.t}}{price_{i,t}} \tag{3.4}$$

4) TR: The ratio at month m is calculated as: number of shares traded in month m/number of share outstanding.

$$TR_{i,m} = \frac{\sum_{t=1}^{n} trading\_volume_{i,t}}{share\_of\_outs\tan ding_{i,m}} \tag{3.5}$$

5) R/DVOL: average the daily ratio of absolute return/dollar volume over month m [7]:

$$R/DVOL_{i,m} = \frac{1}{n}\sum_{t=1}^{n}(\frac{|RET_{i,t}|}{DVOL_{i,t}}) \tag{3.6}$$

6) R/TR: average the daily ratio of absolute return/turnover ratio over month m, where daily turnover ratio is obtained by daily trading volume/ share of outstanding.

$$R/DVOL_{i,m} = \frac{1}{n}\sum_{t=1}^{n}(\frac{|RET_{i,t}|}{TR_{i,t}}) \tag{3.7}$$

where $TR_{i,t} = \frac{trading\_volume_{i,t}}{share\_of\_s\tan ding_{i,t}}$

Except the spread and relative spread are accessible after the year of 1990, the rest of four liquidity measures are available in whole time range (1962-2011). The monthly data statistics description is pooled by the time-series averages of the cross-sectional; the results are displayed in Table 3.1.

Furthermore, I also report the time-series average of the monthly cross-sectional contemporaneous correlations coefficient of the above variables (monthly data and liquidity measures) in Table 3.2. The coefficients are given in the below pair-wise matrix

[7] Ben Rephael etc (2015) adjust for inflation as in time-series tests. However, it is not significantly different regarding the results. In time-series analysis, it is important to control for inflation factor, considering that the element of dollar volume is highly related with inflation; it may lead to spurious results without inflation adjustment, especially in time-series analysis.

(the correlations coefficient between spread, relative spread and other variable are reported after 1990 due to data availability).

Among those liquidity measures, one could observe that they are significantly positively/ negatively correlated with each other, except between spread and trading activity measures (DVOL and TR). Note that, across all the liquidity measures, any two measures in the same dimension are significantly positive correlated with each other. Among other correlation relationships, the trading activity measures are significantly negative correlated with other liquidity measures; transaction costs (S and RS) are significantly positive correlated with the price impact measures (R/DVOL and R/TR). Turnover ratio is significantly positive correlated with monthly (cumulative) returns, and not surprising, the share price related measures, DVOL, R/DVOL and RS, are correlated with market capitalisation. For the rest variables of stock fundamentals, prices of shares at the end of month are significantly correlated with market capitalizations. Three indicators of firm value and firm performance (BM, EP, DY), are correlated with each other. Same for the three cumulative past return variables.

3.3.2 Variables in Time-series Method

I am also particularly interested in exploration of the market-wide liquidity measures and other market variables on a daily basis, to conduct the complementary examination for the cross-sectional test at the individual asset level. The market-wide liquidity measures chosen are transaction cost (spread, relative spread), trading activity (dollar volume, turnover ratio), and price impact (return to dollar volume and return to turnover ratio). Besides, the daily return process of market portfolio and its related variables are volatility, positive/negative components. Moreover, I consider the momentum effect of market portfolio, by recruiting three variables: RET_{23}, RET_{46} and RET_{712}, which represent the cumulative return from the last three to last two months, from last six to four months and from last twelve to seven months, respectively.

The market-wide variables are computed by aggregating the daily observations of common shares as shown below (i is the securities indicator, N is the number of assets in each trading day t).

The average market-wide spread and relative spread in each trading day are calculated by the following equations:

MS: average of all the available shares' spread in each trading day (the daily absolute spread of individual share is calculated as the difference between closing bid price and ask price).

$$MS_t = \frac{1}{N}\sum_{i=1}^{N}(bid_{i,t} - ask_{i,t}) \tag{3.8}$$

MRS: average of all the available shares' relative spread in each trading day.

$$MRS_t = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{bid_{i,t} - ask_{i,t}}{price_{i,t}}\right) \tag{3.9}$$

The market-wide turnover ratio is the value weighted average of all available shares' TR in each trading day according to the following equation:

$$MTR_t = \sum_{i=1}^{N}\left(\frac{trading\_volume_{i,t}}{number\_of\_shares\_outs\tan ding_{i,t}} * \frac{Cap_{i,t}}{\sum_{i=1}^{N} Cap_{i,t}}\right) \tag{3.10}$$

The market-wide return to dollar volume is calculated by the average of all available shares' measure in each trading day:

$$MR / DVOL_t = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{|return|_{i,t}}{Dvol_{i,t}}\right) \tag{3.11}$$

The market-wide return to turnover ratio is calculated by the average of all available shares' measure in each trading day:

$$MR / TR_t = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{|return|_{i,t}}{TR_{i,t}}\right) \tag{3.12}$$

There are several market-wide variables that are based on the market portfolio, its variance and its bullish and bearish regimes:

The market return is defined as the value weighted daily return according to the following formula:

$$MRET_t = \sum_{i=1}^{N}\left(RET_{i,t} * \frac{Cap_{i,t}}{\sum_{i=1}^{N} Cap_{i,t}}\right) \tag{3.13}$$

The market-wide volatility is defined as the squared market return:

$$VOL_t = MRET_t^2 \tag{3.14}$$

The bullish/bearish components of the market portfolio are given by the following equations:

$$\text{PRET} = \max(0, \text{MRET}) \tag{3.15}$$

$$\text{NRET} = \min(0, \text{MRET}) \tag{3.16}$$

The past performance indicator is based on the cumulative return of the past information as shown below:

Ret_{23}: cumulative market return from (t-66) to (t-44), the prior 3 to 2 months cumulative daily return;

$$RET23_t = \prod_{n=44}^{66} (1 + RET_{t-n}) - 1 \tag{3.17}$$

Ret_{46}: cumulative market return from (t-132) to (t-88), the prior 6 to 4 months cumulative daily return;

$$RET46_t = \prod_{n=88}^{132} (1 + RET_{t-n}) - 1 \tag{3.18}$$

Ret_{712}: cumulative market return from (t-264) to (t-154), the prior 12 to 7 months cumulative daily return;

$$RET712_t = \prod_{n=154}^{264} (1 + RET_{t-n}) - 1 \tag{3.19}$$

The statistic description is presented in Table 3.3, where presents the daily market-wide variables.

3.4. Research Methodology

This chapter implements an APT analysis on an asset pricing framework incorporating the liquidity risk premium, and a time-series causality analysis between the market-wide liquidity measures and several market characteristics.

3.4.1 Cross-sectional Investigation

In order to study the impact of liquidity on the individual asset returns, it is suggested conducting the cross-sectional tests. In particular, before formal tests of regressions, one could observe the fundamental impact of liquidity (presented by the six aforementioned measures) on asset returns, by constructing portfolios on the basis of ascending quantification of the six liquidity measures. Furthermore, one could empirically examine the risk-return trade-off of the trading strategies on liquidity, by applying the Fama-MacBeth (1973) cross-sectional model. The following is the procedure for the two parts of examination.

The formation of the liquidity portfolios is accomplished by ranking the stocks. Specifically, in each month m, stocks are ranked by liquidity in month m-1 constructing 5 portfolios on the corresponding percentiles, i.e. [0-20], [20-40], [40-60], [60-80] and [80-100]. The monthly equal-weighted portfolio[8] returns are calculated while a long-short trading strategy is formed, according to which a portfolio of undervalued (illiquid) shares is bought and a portfolio of overvalued (liquid) is short-sold. Insights about the statistical significance of the strategy's payoff, is obtained through the t-test:

$$t_{(5-1)} = \frac{(\overline{R_5} - \overline{R_1})}{\sqrt{\sigma(R_1)/T + \sigma(R_5)/T}} \tag{3.20}$$

where R1 and R5 are monthly equal-weighted returns for portfolio 1 and 5, respectively. T is the number of monthly observations for portfolios. The t-statistics measures how significant of portfolio 1 are different from portfolio 5. Table 3.4 provides a descriptive analysis of the liquidity portfolios' performance and the long-short trading strategy for the whole period and for the eight sub-periods. The t-statistic results displayed in Table 3.4 by the Equation (3.20) is in order to compare how significant of the top portfolio (portfolio 5) be away from the bottom one (portfolio 1). Panel A is about the transaction cost, panel B to the trading activity and finally panel C, to the price impact component.

Note, in order to consider the impact of financial conditions on the effect of liquidity on asset returns, as discussed in the introduction section 3.1, one would split the whole sample

[8] The empirical results of cross-sectional investigation provide similar results from either equal-weighted or value-weighted portfolio returns, regarding the portfolio returns pattern from top to bottom; the significance of long-short portfolio returns are the same in both equal-weighted and value-weighted portfolios.

horizon into eight non-overlapping sub-periods according to the most recent announcements of the US Business Cycle Expansions and Contractions from NBER's Business Cycle Dating Committee. The peak month to next peak month is recognized as one Business Cycle. Thus, there exist the following sub-periods in the sample: from Jan. 1962 to Dec. 1969, from Jan. 1970 to Nov. 1973, from Dec. 1973 to Jan. 1980, from Feb. 1980 to July 1981, from Aug. 1981 to July 1990, from Aug. 1990 to March 2001, from April 2001 to Dec. 2007, from Jan. 2008 to Dec. 2011. Each sub-period consists of an expansion and a recession, and it helps to compare the liquidity effect of different sub-period in a fair way.

After fundamental findings via portfolios construction on the basis of the quantitative of liquidity measures, one also would like to conduct more formal test to examine the effect of liquidity on asset returns. Brennan, Chordia, and Subrahmanyam (1998) argue that the empirical findings based on the portfolio returns are difficult to interpret, and it is suggested conducting the cross-sectional tests on individual assets. Specifically, I adopt Liu's (2006) approach and empirically examine the risk-return trade-off of the trading strategies on liquidity, applying the Fama-MacBeth (1973) cross-sectional model, controlling for several effects on firm fundamentals. The Arbitrage Pricing Theory (APT) specification that applied in this chapter is the following:

$$R_{i,m} - R_{f,m} = c_0 + \sum_{k=1}^{K} \beta_{i,k} f_{k,m} + \sum_{n=1}^{N} c_n Z_{n,i,m} + \varepsilon_{i,m} \tag{3.21}$$

where $R_{i,m}$ is monthly asset return, $R_{f,m}$ is risk free rate, US one-month T-bill rate, $\sum_{k=1}^{K} \beta_{i,k} f_{k,m}$ indicates the sum of premium of risk characteristics which are presented by the Fama-French factors $f_{k,m}$ in this chapter and estimation of loadings $\beta_{i,m}$, and $Z_{n,i,m}$ is the value of non-risk characteristic n of firm i in month m. Hence, the statistic model could be written as:

$$R^{*}_{i,m} = c_0 + \sum_{n=1}^{N} c_n Z_{n,i,m} + \omega_{i,m} \tag{3.22}$$

where $R^{*}_{i,m}$ is risk-adjusted return, $R_{i,m} - R_{f,m} - \sum_{k=1}^{K} \beta_{i,k} f_{k,m}$, and $\beta_{i,k}$ are estimated using a 60-month rolling window. For the purposes of the rolling window estimation, I require at least 24 in 60 monthly data for each stock. The first rolling estimation starts from 30 monthly observations, and then extents to 31, 32..., until it reaches 60 observations.

The procedure for the regression of cross-sectional examination is straightforward, and the followings are some specifications.

First, the asset returns are generated by a K-factor approximate factor model. This risk adjustment procedure is imposed by assumptions that the zero-beta return equals the risk-free rate, and that the APT factor premium is equal to the excess return on the factors. For robustness check, using two different dependent variables (excess return, $R_{i,m} - R_{f,m}$, and risk adjusted return, $R^{*}_{i,m}$), I examine empirically the cross-sectional asset returns and the existence of various liquidity risk premia.

Second, the non-risk characteristics $Z_{n,i,m}$ in equation (3.22) are liquidity measures as well as other control variables, in order to improve the efficiency of the estimate of the coefficients of liquidity: firm size (CAP), Book-to-Market ratio (BM), Dividend Yield (DY), Earnings-Price ratio (EP), momentum cumulative returns (Ret_{23}, Ret_{46}, and Ret_{712}), and the reciprocal monthly prices (1/P). The use of Cap and BM are following Fama-French (1993) who discover that the firm size and Book-to-Market ratio are negatively and positively related to asset return, respectively. Firm characteristics DY and EP are also highly associated with shares return according to various literatures. In spirit of Jegadeesh and Titman (1993), the asset return is highly related to the momentum effect, and the variables of cumulative past returns could proxy the effect to some extent. Besides, I am also mindful of Lee and Swaminathan's (1998) argument that the turnover may be a less than perfect proxy for liquidity because the relation between turnover and expected returns depends on how stocks have performed in the past. Thus, I employ the prior cumulative monthly return, Ret_{23}, Ret_{46}, and Ret_{712} in the cross-sectional regression test. Finally, based on Miller and Scholes (1992), the low price assets are in financial distress, thus, I control the variable of reciprocal of share prices at the end of month.

Third, the Fama-MacBeth analysis is conducted using two lags in the set of the independent variables (m-2). The lag of firm characteristics is adopted in extant literature (e.g. Brennan, Chordia, and Subrahmanyam (1998), Chordia, Subrahmanyam and Anshuman (2001), Pereira and Zhang (2010)) in order to overcome the thin trading effect. Besides, all of the variables are taken logarithms in order to improve the efficiency of estimations.

Fourth, the examination of the multifactor model is implemented through the t-statistic of the Fama-MecBeth (1973) approach. Table 3.5 reports the cross-sectional estimation of slopes of characteristics as the time-series mean $\overline{c}_{i,j}$, as well as the t-statistic of the estimation coefficients t_c in the cross-sectional regressions.

$$\overline{c}_{i,j} = \frac{1}{M}\sum_{m=1}^{M}\hat{c}_{i,j,m} \tag{3.23}$$

$$se(c) = \sigma(c)/\sqrt{M} \tag{3.24}$$

$$t_c = \frac{\overline{c}}{se(c)} \tag{3.25}$$

where $\widehat{c}_{i,j,m}$ is the estimated coefficient of the jth characteristic of the ith asset in month m, σ(c) is the sample standard deviation of the cross-sectional regressions estimates and M is the number of observations. The mean of time-series slopes of non-risk characteristics is reported: significant and positive coefficients indicate possible positive relationship between return and control variables, and vase verse.

Finally, similar to the method of portfolio construction aforementioned in this section, the whole sample horizon is again divided into eight non-overlapping sub-periods based on the US Business Cycle Expansions. The sub-periods in our sample are: Jan 1962 to Dec. 1969, Jan 1970 to Nov 1973, Dec 1973 to Jan 1980, Feb 1980 to July 1981, Aug 1981 to July 1990, Aug 1990 to March 2001, April 2001 to Dec 2007, Jan 2008 to Dec 2011. By the sub-periods, one is able to consider the impact of financial conditions on the relationship between liquidity and return, further to the observed patterns from constructed liquidity portfolio, when other control variables are included in the regression tests. Within each sub-periods based on business cycle theory, there is one expansion and one recession; the empirical results in this section, however, are obtained by averaging the estimated coefficients of liquidity variables in monthly cross-section regressions. Thus, allowing a business cycle as a sub-period ensures a fair comparison of the liquidity effect on asset returns, especially among sub-periods. In particular, it is conjectured to obtain various results in each sub-period under different liquidity measures, and one may conclude that some certain liquidity measures reflect the impact to return under certain market conditions, saying differently, the liquidity measures are heterogeneity and the significance of liquidity measures is time-specific. The time-varying impact of liquidity measures on asset returns across business cycles could potentially be resulted from the influence by market states, i.e., market volatility, market returns and past performance.

3.4.2 Time-series Test

The comparative analysis of the liquidity risk premia is followed by a time-series analysis that aims to account for the potential bidirectional relationships between liquidity and market characteristics. A vector autoregression (VAR) representation, of market-wide liquidity measures and market characteristics, is employed in order to investigate the potential causality effects between the liquidity components and the market dynamics.

As discussed in the section of 3.1.1, the empirical evidence from literature demonstrates that there exists an association among the three categories of liquidity measures: transaction cost, trading activity, price impact, as well as asset returns, in the time-series dimension. For instance, Kyle (1985) provides evidence that high volume is related to low price impact, and Foster and Viswanathan (1990) predict that the high trading activity leads to the low transaction cost. According to Chordia, Sarkar and Subrahmanyam (2005), both the market returns and volatility are informative in predicting the fluctuation of liquidity. Besides, complementary to the evidence from the cross-sectional test of the individual asset liquidity and return, there is a demand of the examination of liquidity at the market level. Therefore, one is motivated to detect possible interdependencies and bidirectional causal effects between these market-wide observations of liquidity measures and market characteristic variables.

This chapter estimates a vector autoregression (VAR) which retains liquidity measures and market characteristic variables. The causality effects are investigated by daily frequency time-series data. In particular, the market-wide liquidity components are transaction cost, trading activity and price impact, while the market variables of conditions are the return sign (PRET, NRET), the market volatility (VOL) and the momentum proxies (Ret_{23}, Ret_{46}, and Ret_{712}). The computation of the variables is explained in the section of Data. Note that the use of market direction variables PRET and NRET allows a nonlinearity relation according to Chordia, Roll and Subrahmanyam (2001); market volatility and momentum effects are substantially associated with liquidity, so they are controlled in the model.

Since a VAR model requires stationary data process, the variables are examined as follows. The Dickey-Fuller tests dictate that the return-based variable (MR/DVOL, MR/TR, MRET, VOL, PRET, NRET, Ret_{23}, Ret_{46}, and Ret_{712}) are stationary; on the other hand, I transform the price-related variables (MDVOL, MTR, MS, MRS) by taking first difference: $\Delta x_t = x_t - x_{t-1}$, where x denotes MDVOL, MTR, MS and MRS, respectively. Then I conduct the Augmented Dickey-Fuller (ADF) test on the transformed variable Δ MDVOL, Δ MTR, Δ MS and Δ MRS, the unit root is strongly rejected, namely, all of the first difference daily transformed variables are stationary process. Therefore, one can employ these variables in the VAR and conduct the Granger Causality test.

Thus, I apply the conventional Granger Causality test by using either the liquidity measures per se or their first differences as the ADF test suggests.

Consider the following VAR system:

$$X_t = \sum_{l=1}^{L} A_l X_{t-l} + u_t \tag{3.26}$$

where X_t are MR/DVOL, MR/TR, MRET, VOL, PRET, NRET, Ret_{23}, Ret_{46}, and Ret_{712}, of which 9 market-wide variables at the daily basis, and the construction details are described in the Section of Data 3.3, as well as another 4 variables which are transformed from original non-stationary market-wide observation process, by taking first difference, Δ MDVOL, Δ MTR, Δ MS and Δ MRS. Hence, there are 13 market-wide variables at the daily basis. The matrix A_l represents the coefficients to be estimated in the multivariate regressions. In empirical estimations, it determines number of lags, L, as 20, following the convention of one month (20-22 trading days) lagbvof fundamental effect on asset returns.

The pair of the hypotheses under investigation is:

H0: any one specific variable in X_t does not Granger cause other variables (the 20 coefficients associated with the one specific variable are jointly zero in the VAR estimation equation) and H1: not H0.

In other words, if *k* and *q* stands for one of the market-wide variables (liquidity measures or market characteristics) as stated above, for the null hypothesis that variable *k* does not Granger cause variable *q*, I test whether the lag coefficients of variable *k* are jointly zero when variable *q* is the dependent variable in the VAR equation.

3.5 Empirical Findings

The empirical results analysis of this chapter contains two parts, which are obtained from the investigations by the cross-sectional method and time-series analysis. The cross-sectional results consist of a descriptive analysis and a model-based one regarding the three components of liquidity, that is, the transaction cost, the trading activity and the price impact. In particular, I present the significance of the long-short payoffs on liquidity portfolios and the liquidity risk premium on an asset pricing framework by the Fama-MacBeth regressions. The time-series investigation is conducted on the market-wide variables, through examining the coherence between the liquidity measures and estimating the pair-wise Granger causality tests between the VAR's variables.

3.5.1 Results from Cross-sectional Method

In order to have a picture of the relationship between liquidity and individual asset return, it is intuition to observe the fluctuation of returns of portfolios. The portfolios are constructed on the basis of liquidity measures quantity, and the portfolios returns are computed equal-weighted over the shares. The results of the long-short payoffs on liquidity portfolios are displayed in Table 3.4 and they are described along with the regressions results in the section 3.5.1.1, 3.5.1.2 and 3.5.1.3, which discusses the results regarding the transaction cost, trading activity and price impact, respectively.

In the cross-section investigation, the Fama-MacBech method (1973) is employed to estimate the loading of liquidity values against asset return, after controlling other fundamental variables in the regressions. In other words, I conduct the cross-sectional OLS regressions, where the dependent variables are individual assets return or risk-adjusted return as described in Section 3.4.1, and the independent variables are the value of liquidity variables and other non-risk fundamental characteristics. Note that two sets of dependent variables are examined: the asset excess return and the abnormal return, which are stocks monthly return excess to the risk free rate and adjusted by Fama-French factors, respectively. The controlling variables are firm size (CAP), book-to-market ratio (B/M), dividend yield (DY), momentum proxies Ret_{23}, Ret_{46}, and Ret_{712} as the cumulative returns of prior months, as well as the reciprocal of share prices at the end of month. By convention, additional one lag of independent variables is added to avoid spurious relation due to the effect of thin trading. The estimated coefficients of the fundamental characteristics are averaged in time-series. The averaged estimation of coefficients is obtained in each sub-period (Business Cycle), along with the corresponding t-statistics, which are taken by the time-series estimation of coefficients in sub-periods or in whole sample horizon. According to the empirical findings, the estimated coefficients of independent variables in the set of excess return are nearly consistent with the results in the set of abnormal returns.

3.5.1.1 Transaction Cost

Regarding the transaction cost, there are two liquidity measures as proxies. The monthly spread is averaged by the daily spreads (the difference between ask prices and bid prices), while the relative spreads are obtained by the ratio of the absolute spreads over prices. Both of the two measures are adopted to present the transaction costs of shares. The popular notion that liquidity may impact returns through a premium for greater trading costs was first discussed in Amihud and Mendelson (1986). They claim that the stock excess return is a concave function of stock relative spread, which is test on the annual basis.

I first focus on the liquidity portfolios' patterns in Panel A of Table 3.4, where the excess returns increase from portfolio 1 to portfolio 5 in sub-period 6 and 7, with significance difference between the top and bottom portfolios returns. However, only the relative spread portfolios could provide a significant increasing pattern from portfolio 1 to portfolio 5. Nevertheless, the increasing pattern reverses in sub-period 8. Besides, the mimicking portfolios returns of relative spread are higher than that of spread, i.e., the latter portfolios are slightly lower than 1% on average per month (12% per annum) in sub-period 6 and 7, while the relative spread mimicking portfolios are higher than 1.5% (18% per annum), in those two periods and 1.17% (14% per annum) average in the whole sample horizon.

I further explore this through the cross-sectional regressions and it is found that both of the measures (S, RS) are priced in the market providing a liquidity risk premium. In Table 3.5, the estimation of coefficients and their corresponding t-statistics are displayed beneath. The results are obtained in each sub-period and whole period. According to the Panel A and

Panel B of Table 3.5, it is observed that the coefficients of spread and relative spread are significant and positive in period 6 and 7 (from Aug 1990 to Dec 2007) and in whole sample period from 1990 to 2011, but insignificant in sub-period 8. The results from the mimicking portfolios as well those from the asset pricing model are similar, furthermore, during the last sub-period the portfolios provide a negative pattern on liquidity which is actually not priced on the asset pricing model. Regarding the coefficients of the controlling variables, I also found that those are profitability (EP and DY) along with the prices and the past performances are significant in this model. In specific, it is noticed that the coefficients of BM and EP are both significant in sub-period 7. The variable CAP is not persistently negative and significant over the sample sub-periods. The share price variable is positive and significant in all the sub-periods and whole horizon. In terms of the momentum proxies, only RET_{46} are significant period 6 and whole horizon, while RET_{23} and RET_{712} are insignificant related with asset return when other control variables are in presence.

Focusing on the relationship between the asset return and transaction cost, I provide evidence that the portfolio patterns are increasing in period 6 and 7, but decreasing in period 8. The similar results are confirmed from the regression tests. In particular, the estimated coefficients of spread and relative spread are positive and significant in sub-period 6 and 7 also in the whole sample period; however, insignificant in period 8. Since the coefficients of CAP are negative and significant either from spread or relative spread, while in other sub-period they are not, it is surmised that the insignificance results in period 8 is due to the dominant of asset size effect.

3.5.1.2 Trading Activity

A number of measures are suggested to evaluate the trading activities in literature; however, some of them are not accessible especially for a long horizon. In this chapter, I use the turnover ratio and the dollar volume measures. Literature argues the implication and effect of high trading on asset return. Brennan, Chordia, and Subrahmanyam (1998), and Chordia, Subrahmanyam and Anshuman (2001) suggest that the asset with high turnover ratio or dollar trading volume is supposed to yield negative premium, and the empirical results support the hypothesis. In contrast to the above findings, Brown, Crocker, and Foerster (2009) discover positive association between turnover ratio and asset returns in big size firms, and suggest that the effect of turnover ratio might be dominated by information and momentum effect. The inconsistence of empirical results motivates us to conduct the analysis.

The mimicking portfolio analysis suggests that high values of the turnover ratio and low values of the dollar volume are associated with higher returns and the result which is consistent with the risk premia analysis only for the dollar volume measure. One could observe the pattern of portfolio returns from the top to bottom, where the portfolio 1 (P1) contains the assets with lowest monthly dollar volume or turnover ratio, while portfolio 5 (P5) is constructed by most heavily traded assets. It is observed that the dollar volume portfolio's mean returns decrease from P1 to P5 in majority of sub-periods, and the turnover ratio portfolio's time-series mean returns increase from P1 to P5 in all of the sub-periods. The mimicking portfolio returns, i.e. the differences between the top and bottom portfolios, are significant in majority of dollar volume portfolio results, though the significant increasing pattern is presence in period 7 and 8. In terms of the turnover ratio portfolios, all the differences between P1 and P5 and significant in both sub-periods and whole sample period are significant. Through the descriptive analysis it is found that a positive relationship between TR and returns which is in line with Brown, Crocker, and Foerster (2009) (for big size firms) and a negative one regarding the DVOL consistently with Brennan, Chordia, and Subrahmanyam (1998), and Chordia, Subrahmanyam and Anshuman (2001). In one word, the different patterns of returns of dollar volume and turnover ratio portfolios are rather surprising, because these two measures are essentially derived from the same source, and they both measure the trading activity, which is the same dimension of liquidity.

The regression results suggest that the slopes of turnover ratio and dollar volume are estimated as negative coefficients in most of the sub-periods and whole sample period. The results of DVOL penal provide negative returns during the analysis (either with the mimicking portfolios or the cross-sectional analysis) with an exemption to the last two sub-periods. The results in Panel C of Table 3.5 report that, 7 of 9 (time-series average) coefficients estimation of dollar volume are negative, and are statistically significant in period 2, 5 and whole sample horizon. The closely similar results of turnover ratio in Panel D Table 3.5: 7 of 9 (time-series average) coefficients estimation are negative, and significant in the same sub-periods as dollar volume. Similar results have been found in literature. Brennan, Chordia, and Subrahmanyam (1998), and Chordia, Subrahmanyam and Anshuman (2001) suggest that assets with high turnover ratio or dollar trading volume are supposed to yield negative premium. They further examine the premium of trading activity on the individual assets aspect. It implies that the stocks with low dollar trading volume or turnover ratio require high return premium. That is not surprising, and could be explained by our results in sub-section 3.5.2, i.e. the high correlation and strong bidirectional Granger causality between dollar volume and turnover ratio.

It is noticeable that the turnover ratio portfolios' return pattern does not agree with the regression results. From Table 3.4, one can observe that the returns of dollar volume portfolio decrease from P1 to P5, while returns of turnover ratio portfolio increase from P1 to P5. But this is not a contraction, due to two reasons as follows. First of all, the trading activity measures, in this chapter, turnover ratio or dollar volume, do not indicate the precise relationship between liquidity and asset return, before balancing out the noise which is resulting from the other pricing factors. Brown, Crocker, and Foerster (2009) found a positive association between turnover ratio and asset return in big firms, and suggest that the effect of turnover ratio might be dominated by information and momentum effects. Similar findings have been reported in Pástor and Stambaugh (2003), which claims that "it is often the case that volume is high when liquidity is low". Secondly, though the return of portfolios constructed on the turnover ratio or dollar volume generate almost opposite patterns, the regression results, especially the estimated coefficients of turnover ratio or dollar volume, are extremely similar, not only in the positive or negative signs of coefficients, but also in the magnitudes in the sub-periods. The inclusion of the control variables in the analysis (CAP, B/M, EP, 1/P and momentum proxies) seems to play a significant role on this relationship and offsets the positive significant TR effect. Those control variables balance out the noise effect which affects the asset return as displayed from the portfolio results in Table 3.4.

Moreover, the CAP variable is more significantly priced along with TR than with DVOL. This might be due to the high correlation between DVOL and CAP which possibly implies a size domination effect. The results with the presence of R_{46} coefficients are more significant than that of RET_{23} and RET_{712}, in both cases. Overall, in the sample period of 1962 to 2011, the dollar volume and turnover ratio are both negative and significantly related to the asset excess returns, after the CAP, BM, EP, momentum proxies and share prices are controlled; the CAP and EP coefficients are insignificant when the trading activity is in the presence of DVOL.

It is worth mentioning that the magnitude of the coefficient of trading activity is higher during the second sub-period (i.e. Jan. 1970 to Nov. 1973). This is in line with Brennan, Huh, Subrahmanyam (2012), who claim that the liquidity risk premium is apparent mostly in down-side market conditions, as well as Pástor and Stambaugh (2003) that the market liquidity is generally low in the early 1970s. The finding is also notable that dollar volume and turnover ratio both capture similar quantities of liquidity coefficient regarding the risk premia, in terms of its effect on asset returns.

3.5.1.3 Price Impact

Price impact is an essential aspect of liquidity. The trading of a certain amount of shares without changing the prices is denoted as the circumstance of high liquidity. Inspired by Kyle (1985), which studies the ratio of price change per unit of the net order flow, several researchers propose price impact measures to proxy liquidity, for instance, return to dollar volume (R/DVOL) by Amihud (2002) and return to turnover ratio (R/TR) by Florakis, Gregoriou, and Kostakis (2011). The latter employs the turnover ratio instead of dollar volume to involve the trading activity in order to isolate the monetary effect and size bias for relative big firms. Our findings are, in general, consistent with those of Florakis et.al. (2011).

The portfolios are constructed on the basis of the price impact, R/DVOL or R/TR. The portfolio 1 (P1) is constructed by the assets with lowest price impact, while portfolio 5 (P5) has high price impact assets. The portfolios are rebalanced on monthly basis. The time-series mean returns of portfolios over each sub-period and whole sample horizon are reported in Panel C of Table 3.4. Moving from P1 to P5, one could observe the obvious increasing patterns in the R/DVOL portfolios, and a majority of the difference between the returns of P1 and P5 are significant except in period 4 and 8. On the other hand, the significant decreasing pattern from P1 to P5 is obvious among the R/TR portfolios, except in period 5 and 6. Specifically, the time-series mean returns of P1 are higher than P5 in whole sample period and most of the sub-periods. The differences between the top and bottom portfolios are significant. The portfolio results of R/DVOL and R/TR are consistent with the findings in Florakis, Gregoriou, and Kostakis (2011) which employ the LSE shares data and rank stocks into 10 portfolios.

Moreover, the price impact incorporates several structural changes with respect to the Business Cycles. According to Panel E and F of Table 3.5, it is found that the estimation coefficients of R/DVOL are significantly positive in sub-period 1, 4, 8 and the whole horizon, while the slopes of R/TR are positive and significant in period 2, 5 and whole sample horizon. The loadings of the price impact in other sub-periods are statistically insignificant. In specific, the positive relationship between R/TR and asset excess returns is stronger in period 2, which is in line with the findings based on DVOL and TR. Another consistent finding in the price impact tests with the trading activity is that the element of DVOL or TR determines the agreement (or disagreement) of the portfolio return pattern and the regressions results. In particular, the portfolio results agree with regression results in terms of the effect of DVOL and R/DVOL on asset returns, while those by the liquidity measures of TR and R/TR are opposite.

The insignificant results of the momentum and size control variables indicate that effect of R/DVOL dominates the size and the past performance effects. The momentum variables (RET_{23}, RET_{46}, and RET_{712}) are insignificant when using R/DVOL in the whole sample period, in contrast to that of R/TR.

3.5.2 Results from Time-series Investigation

In this section, the market-wide liquidity and market variables are examined in time-series dimension. In specific, they are examined by both contemporaneous correlations and pair-wise Granger-causality tests, and the latter tests are conducted by VAR, which aims to account for the potential bidirectional relationships between liquidity and market characteristics.

3.5.2.1 Contemporaneous Correlation

By investigation of the market-wide variables, I examine the coherence between the liquidity measures as shown in Panel A of Table 3.6. All the assets variables are aggregated into market-wide processes on daily basis. The contemporaneous correlation matrix is demonstrated in Panel A. The critical value is 0.1, for two tails of significance possibility of 0.001.

I observe that the six market-aggregated liquidity measures are all significantly correlated with each other. The correlation relationship is, in general, consistent with the results of the mimicking portfolios which display the cross-sectional correlation of individual asset monthly liquidity measures (as in Table 3.2). Each pair of liquidity measures which are in the same dimension of liquidity (i.e. transaction cost, trading activity or price impact) are positively correlated with each other. Moreover, the trading activity measures, MDVOL and MTR, are significantly negative correlated with any other measures, while the transaction cost measures, MS and MRS, are significantly positive correlated with price impact measures, MR/DVOL and MR/TR.

Besides, the correlation between the three categories of market-wide liquidity measure and the market portfolio return-related variables are also very interesting. Specifically, the correlation coefficient between MDVOL and VOL, PRET, NRET is 0.16, 0.15 and -0.14, respectively; while the correlation coefficient between MTR and VOL, PRET, NRET presume a similar pattern, 0.25, 0.21, and -0.20, respectively. Thus, the market volatility affects the inventory risk and due to its impact on market liquidity via trading activity. The opposite signs of the coefficients between the trading activity (MDVOL and MTR) and PRET or NRET, provide insights on that the trading could be heavier in either up-market or down-market, an assumption which is also addressed by Pástor and Stambaugh (2003). In addition, the correlation coefficient between the price impact measures (MR/DVOL and MR/TR) and momentum variables (RET_{23}, RET_{46} and RET_{712}) are also significantly positive. It is suggestive that the past performance has relative high influence on price impact measures. This argument is not in line with the results of individual liquidity measures, as TR is significantly correlated with the momentum variables (RET_{23}, RET_{46} and RET_{712}), while in the market-wide scene, the price impact measures (MR/DVOL and MR/TR) instead of TR are correlated with past returns.

3.5.2.2 Granger Causality

The pair-wise Granger-causality tests between the market-wide variables of the VAR are presented in Panel B of Table 3.6. With the null hypothesis, which is that variable *k* does not Granger-cause variable *q*, where *k* and *q* stands for one of the 13 market-wide variables (liquidity measures or market characteristics), I test whether the lag coefficients of *k* are jointly zero when *q* is the dependent variable in the VAR. In the matrix of Panel B, the cell associated with the *k*th row variable and the *q*th column variable shows the p-value associated with this test. For clearer vision, I organize the p-value matrix into Panel C, which displays the null hypothesis results that one variable in column does not granger cause other variables in row.

The fundamental investigation is on the Granger causality of one specific liquidity measure by other measures. For instance, MDVOL Granger causes MTR, MR/DVOL, MR/TR, but is not Granger caused by MS and two price impact variables MR/DVOL and MR/TR; similarly, MTR does not Granger cause transaction cost variables MS and MRS, but price impact proxies MR/DVOL, MR/TR; however, price impact variables does not Granger cause MTR. Furthermore, trading activity proxies Granger causes price impact variables, but the causality is not bidirectional. MRS Granger causes any other liquidity measures, but it is only Granger caused by price impact variables and same liquidity dimension variable MS. Any liquidity measure Granger causes MR/DVOL or MR/TR, but both these two measures Granger cause only MRS. To sum, the bidirectional relationships exist within each dimension of liquidity measures, and also between MRS and price impact measures (MR/TR or MR/DVOL), while the three liquidity measures, MRS, MR/TR and MR/DVOL are Granger caused by all the other liquidity measures. All liquidity measures have a unidirectional causality relationship with trading activity measures. Figure 3.2 illustrates the Granger causality between six market-wide liquidity measures from three dimensions.

With respect to the relationship between market-wide characteristics and liquidity measures, it is discovered that the bidirectional causality exists. For instance, the market state variables, VOL, PRET and NRET, Granger cause price impact and trading activity variables, respectively; meanwhile, market-wide price impact and trading activity measures also Granger cause VOL, PRET and NRET, respectively. By other words, these characteristics are associated with price impact or trading activity measures in a bidirectional relationship. Note that the variables of VOL, PRET or NRET do not Granger cause transaction cost proxies. The Granger causalities between these variables are illustrated in Figure 3.3.. The Granger causality by all of the three momentum variables to MTR is significant, and RET_{23} Granger causes DVOL, but does not cause price impact or transaction cost variables. Conversely, only MR/TR and MR/DVOL Granger causes one of the momentum variables RET_{23}; trading activity proxies MDVOL and MTR Granger cause the momentum variables RET_{46} and RET_{712}. The Granger causality detected in this section explains that market past performance is caused by liquidity, especially the dimensions of trading activity and price impact, and subsequently, the market-wide trading activity affects the market portfolio most recent and further performance.

3.5.3 Specification Issues

First, the dataset in this chapter considers tapes from 1962 to 2011 in CRSP and COMPUSTAT. The whole sample of fifty years is covered by eight business cycles which count from one peak to the next. The most recent peak refers to December of 2007, followed by a global recession in 2008 and 2009; as discussed in previous sections, one sub-period contains one expansion and one recession, thus, time-series average estimation of slopes is comparable among sub-periods, providing possibly distinguish effect in expansion and recession. However, in this study, the dataset stops in 2011 when is not an end of existing business cycle. Ben-Rephael et al. (2015) suggest that market liquidity significantly reduces in recent years due to technical trading mechanism, and liquidity premium also declines. Though Ben-Rephael et al. (2015) do not study the data after 2011, it is well known that high frequency quantitative trading improves market liquidity by a dramatic increase in trading activity. Hence, without the empirical tests after 2011, one is not able to analyse the empirical results of the last sub-period from 2007 to 2011 as one entire business cycle, and thus, the results are not comparable with other sub-periods.

Second, this chapter studies liquidity premium by various liquidity measures, and divide whole sample horizon into sub-periods based on business cycles. Business cycles are fluctuation of economic activities; a cycle consists of an expansion and a recession or contractions. Since the recessions are much shorter and less common, the expansion is the default mode of the economy. In this study, one business cycle starts from a peak to next peak; an expansion is from previous trough to a peak, while a recession is from previous peak to a trough. It is recognized that "recessions can extract a tremendous toll on stock markets"[9]. The intuition is that liquidity premia vary over time and the variation is related to the expansion and recession pattern. Based on the consideration of "flight-to-liquidity", in recession or even around trough period, investors prefer to choose quality or liquid assets, thus, those illiquid assets require higher returns as compensation. In this study, the main reason, of not including the examinations of differential premium in expansions and recessions, is that, in some recessions, there are not enough observations for regression estimations, e.g. January 1980 to July 1980. For future research, it would propose to conduct empirical studies by either adding a switching dummy variables in order to indicate troughs, or examining at higher frequency in order to allowing more observations for regression estimation.

3.6 Conclusion

A naïve way to understand liquidity is by considering the easiness that an asset is traded at low transaction cost with little price impact and this is quantified by different proxies on trading quantity, trading speed, trading cost and price impact. Based on their implications for stock returns, the measurement can be classified into three categories: transaction cost (absolute spread, relative spread), trading activity (turnover ratio and dollar volume) and price impact (return to dollar volume, return to turnover ratio), according to extant literature.

[9] For instance, in the Great Recession, most major equity indexes declines for over 50% during 18 months; from 2001 to 2002, Nasdaq jumped for around 80%.

This thesis focuses on the liquidity measures under a comparative framework using data from CRSP over the period 1962 to 2011, through cross-sectional and time-series approaches. The former investigation on the cross-sectional dimension employs the conventional Fama-MacBeth approach controlling for several factors on firm fundamentals; while in the study in the time-series dimension by the latter method, the interaction of liquidity dimensions and information indicators is studied at the market-wide level.

The empirical findings of this chapter are summarized as follows.

First of all, the results from cross-sectional examination are consistent with the foundations of liquidity measures, although several structural changes that have taken place during the examined time period. Additionally, the empirical results in this thesis suggest that the significance of liquidity is time specific, in other words, the heterogeneity between liquidity components exhibits a strong Business Cycle effect. In particular, the liquidity risk premium is strengthened during downturns of the market conditions, as the association between the asset liquidity and return in the cross-sectional dimension is relatively stronger in the period of lower market liquidity.

Moreover, there is evidence that the trading activity component of liquidity dominates conventional risk factors such as the size effect. Similar results are obtained with the R/DVOL which dominates the size and the momentum effects.

Furthermore, interesting Granger causality relationship is detected. The analysis is carried out that focuses on the interrelationship between the market-wide liquidity components and the market dynamics. Bidirectional causality exists within the same category of liquidity measures, and between transaction cost and price impact measures. Price impact components are Granger caused by transaction costs and trading activity, but do not Granger cause trading activity.

Finally, it is found that the market-wide characteristics (VOL, PRET or NRET) affect the trading activity and the price impact liquidity components and subsequently the past performance of asset returns. That is, the bidirectional causality exists between VOL, PRET or NRET and price impact or trading activity measures, but return-related indicators do not cause transaction cost proxies. The Granger causality detected in this section also explains that market past performance is caused by liquidity, especially the dimensions of trading activity and price impact, and subsequently, the market-wide trading activity affects the market portfolio most recent and further performance.

Table 3.1 Statistics description of cross section variables

This table domenstrates the statistics of monthly variables, which are going to be used in the cross-sectional regrssions. The mean, median, standard deviation are obtained by the time-series average of monthly cross-sectional mean, median, standard deviation. The listed variables are observed or calculated from a sample of average 2050 NYSE-AMEX firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. The control variables are reported in Panel A. RET is the monthly return of assets. CAP is the market capitalizations of firms. PRICE denotes the closing prices at the end of month. B/M is the book-to-market ratio, obtained by the ratio of last year's book value to the market prices at the end of each month. EP is the earning price ratio. DY is the divided yield, which is calculated by the sum of last year's dividend over the prices at the end of each month. Ret 23, Ret46, Ret712 are cumulative returns of over the second through third, forth through sixth, and seventh through twelfith months prior to the present months, respectively. The six variables measure liquidity in Panel B. DVOL denotes sum of daily dollar trading volumes within month for each stock. S is the value of absolute monthly spreads, which are obtained by taking average of the daily absolute spread within each month. RS represents relative spread, namely, the ratio of absolute spread to share closing prices, and the monthly relative spread is the average of daily relative spread. TR is the monthly turnover ratio , calculated by monthly trading volume over number of shares outstanding in each month. R/DVOL denotes the ratio of absolute return to dollar volume, while the monthly R/DVOL is the average daily R/DVOL. R/TR is defined similar to the previous variable, but the absolute return is divided by daily turnover ratio.

Panel A:	**Monthly control variables**								
	RET	**CAP(10^6)**	**PRICE**	**B/M**	**EP**	**DY**	**Ret23**	**Ret46**	**Ret712**
Mean	0.01	1.42	27.05	0.77	0.08	0.03	0.02	0.04	0.07
Median	0.01	0.33	21.50	0.60	0.07	0.02	0.02	0.03	0.06
Standard deviation	0.09	3.51	23.45	0.78	0.15	0.05	0.13	0.16	0.21

Panel B:	**monthly liquidity measures**					
	DVOL(10^6)	**S**	**RS**	**TR**	**R/DVOL(10^-6)**	**R/TR**
Mean	130.05	0.23	0.01	68.23	0.24	0.02
Median	25.95	0.20	0.01	45.62	0.11	0.01
Std.deviation	251.79	0.14	0.01	99.61	0.33	0.02

Table 3.2 Monthly Correlation - Pairwise

This table present time-series of monthly cross-sectional correlations between the firm characteristics under investigation in the pricing model. The listed variables are observed or calculated from a sample of average 2050 NYSE-AMEX firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. The first six variables measure liquidity. DVOL denotes the logarithm of sum of daily dollar trading volumes within month for each stock. S is the logarithm value of absolute monthly spreads, which are obtained by taking average of the daily absolute spread within each month. RS represents logarithm of relative spread, namely, the ratio of absolute spread to share closing prices, and the monthly relative spread is the average of daily relative spread. TR is the logarithm of monthly turnover ratio , where the monthly turnover ratio is calculated by monthly trading volume over number of shares outstanding in each month. R/DVOL denotes the logarithm of the ratio of absolute return to dollar volume, while the monthly R/DVOL is the average daily R/DVOL. R/TR is defined similar to the previous variable, but the absolute return is divided by daily turnover ratio. RET is the monthly return of assets. CAP is the logarithm of market capitalizations of firms. PRICE denotes the logarithm of closing prices at the end of month. B/M is the logarithm of book-to-market ratio, which is obtained by the ratio of last year's book value to the market prices at the end of each month. DY is the divided yield, which is calculated by the sum of last year's dividend over the prices at the end of each month. Ret 23, Ret46, Ret712 are cumulative returns of over the second through third, forth through sixth, and seventh through twelfith months prior to the present months, respectively. We use * to denote the significance of the coefficients at 1%.

	DVOL	S	RS	TR	R/DVOL	R/TR	RET	CAP	PRICE	B/M	EP	DY	Ret23	Ret46	Ret712
DVOL	1														
S	-0.024	1													
RS	-0.314 *	0.398 *	1												
TR	0.257 *	-0.035	-0.147 *	1											
R/DVOL	-0.180 *	0.131 *	0.449 *	-0.152 *	1										
R/TR	-0.155 *	0.177 *	0.339 *	-0.232 *	0.523 *	1									
RET	0.035	0.013	0.068	0.312 *	0.090	0.089	1								
CAP	0.750 *	-0.007	-0.281 *	-0.019	-0.136 *	-0.059	-0.056	1							
PRICE	0.446 *	0.445 *	-0.329 *	0.052	-0.221 *	-0.077	-0.060	0.400 *	1						
B/M	-0.039	0.245 *	-0.036	0.002	0.028	0.020	-0.019	-0.053	0.222 *	1					
EP	0.030	0.185 *	-0.111 *	-0.002	-0.054	-0.019	-0.046	0.017	0.254 *	0.524 *	1				
DY	-0.046	0.037	-0.026	-0.132 *	-0.040	-0.001	-0.146	0.002	0.090	0.375 *	0.306 *	1			
Ret23	0.010	0.018	0.067	0.240 *	0.038	-0.019	0.214	-0.069	-0.076	-0.025	-0.061	-0.193 *	1		
Ret46	0.006	0.018	0.069	0.248 *	0.044	-0.020	0.233	-0.078	-0.085	-0.032	-0.071	-0.221 *	0.313 *	1	
Ret712	0.005	0.013	0.063	0.274 *	0.050	-0.025	0.251	-0.090	-0.099	-0.034	-0.070	-0.259 *	0.341 *	0.408 *	1

Table 3.3 Daily market-wide variable

This table documents the statistics of market-wide variables on the daily basis.The listed variables are observed or calculated from a sample of average 2050 NYSE-AMEX firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. Except spread and relative spread are only avaiable after 1990, other variables are available over 1962 to 2011. The market variables are aggregated by all of the avaiable assets in the daily data sample. Panel A demonstrates the market return related vairbales. MRET denotes the market return, which are calculated by the value-weighted daily return of shares. PRET and NRET are decomposed from MRET into the positive and negative strings, namely, positive return process are max (0, MRET), while negative return process are min (0, MRET). VOl is the volatility of market return, calculated by (MRET)^2. Ret23, Ret46, Ret712 are cumulative market returns of over the second through third, forth through sixth, and seventh through twelfith months prior to the present months, respectively. Note, we assume 22 trading days in one month. The variables in Panel B are market-wide liquidity measures process, where MDVOL is market dollar volume, the sum of all available share dollar volume in each trading day. MS is the market spread, calculated by the average of cross-sectional shares spread on daily basis. MRS is the market relative spread, calculated by the average of cross-sectional shares relative spread on daily basis. MTR indicates market turnover ratio, obtained by value-weighted average of assets turnover ratio. MR/DVOL and MR/TR denote the market return to dollar volume and market return to turnover ratio, respectively, and they are derived from daily average of return to dollar volume and return to turnover ratio.

Panel A:	**MRET**	**PRET**	**NRET**	**VOL**	**Ret23**	**Ret46**	**Ret712**
Mean	0.00072	0.00366	-0.00294	0.00010	0.0168	0.0336	0.1359
Median	0.00089	0.00089	-0.00023	0.00002	0.0199	0.0360	0.1369
Std.deviation	0.00986	0.00618	0.00612	0.00044	0.0484	0.0686	0.1436

Panel B:	**MDVOL (10^6)**	**MS**	**MRS**	**MTR**	**MR/DVOL (10^-6)**	**MR/TR**
Mean	16816	0.231	0.012	3.249	0.229	0.018
Median	5185	0.163	0.009	2.318	0.180	0.016
Std.deviation	24090	0.175	0.009	3.200	0.168	0.010

Table 3.4 Mean of time-series monthly return of portfolios constructed by liquidity meaures

All the stocks are ranked on the basis of its monthly liquidity measures, in an ascending order. The portfolios are named by their liquidity measures, and the number in the names of portfolios indicates the rank of liquidity measures' quantity. e.g. in the groups of spread (S), P1 indicates the stocks in this portfolio have lowest spread; while in the groups of R/DVOL, the stocks in portfolio of P5 have the highest R/Dvol. The portfolios are monthly rebalanced, on the basis of month (t-1) liquidity measures, and we report the time-series average return of portfolios in month t. The returns of portfolios are calculated by equal-weighted. The data ranges from:1962 to 2011, where the whole sample horizon is divided into 8 sub-periods according to the Business Cylces, Jan 1962 to Dec. 1969, Jan 1970 to Nov 1973, Dec 1973 to Jan 1980, Feb 1980 to July 1981, Aug 1981 to July 1990, Aug 1990 to March 2001, April 2001 to Dec 2007, Jan 2008 to Dec 2011. The last row in each panel reports values for t-tests referring to the null hypothesis of no difference in means between P1 and P5. We use * to denote the significance of the difference at 5%.

Panel A	***liquidity portfolio***	**whole horizon**	**period 1**	**period 2**	**period 3**	**period 4**	**period 5**	**period 6**	**period 7**	**period 8**
	S: P1	0.0692						0.0634	0.0592	0.0972
	S: P2	0.0749						0.0768	0.0636	0.0897
	S: P3	0.0728						0.0746	0.0649	0.0824
	S: P4	0.0715						0.0762	0.0643	0.0740
	S: P5	0.0700						0.0726	0.0652	0.0728
	S P 5-1	0.0008						0.0092 *	0.0060 *	-0.0244 *
	t-stat	0.6080						4.1252	2.8760	-3.5053
	RS: P1	0.0643						0.0648	0.0558	0.0771
	RS: P2	0.0713						0.0683	0.0633	0.0906
	RS: P3	0.0748						0.0723	0.0631	0.0990
	RS: P4	0.0726						0.0765	0.0631	0.0807
	RS: P5	0.0759						0.0826	0.0727	0.0679
	RS: P 5-1	0.0117 *						0.0178 *	0.0169 *	-0.0092
	t-stat	*8.9723*						*7.5938*	*5.8215*	*-1.5363*

Table 3.4 Mean of time-series monthly return of portfolios constructed by liquidity meaures

All the stocks are ranked on the basis of its monthly liquidity measures, in an ascending order. The portfolios are named by their liquidity measures, and the number in the names of portfolios indicates the rank of liquidity measures' quantity. e.g. in the groups of spread (S), P1 indicates the stocks in this portfolio have lowest spread; while in the groups of R/DVOL, the stocks in portfolio of P5 have the highest R/Dvol. The portfolios are monthly rebalanced, on the basis of month (t-1) liquidity measures, and we report the time-series average return of portfolios in month t. The returns of portfolios are calculated by equal-weighted. The data ranges from:1962 to 2011, where the whole sample horizon is divided into 8 sub-periods according to the Business Cylces, Jan 1962 to Dec. 1969, Jan 1970 to Nov 1973, Dec 1973 to Jan 1980, Feb 1980 to July 1981, Aug 1981 to July 1990, Aug 1990 to March 2001, April 2001 to Dec 2007, Jan 2008 to Dec 2011. The last row in each panel reports values for t-tests referring to the null hypothesis of no difference in means between P1 and P5. We use * to denote the significance of the difference at 5%.

Panel B	***liquidity portfolio***	**whole horizon**		**period 1**		**period 2**		**period 3**		**period 4**		**period 5**		**period 6**		**period 7**		**period 8**	
	TR: P 1	0.0586		0.0476		0.0635		0.0671		0.0711		0.0667		0.0599		0.0467		0.0560	
	TR: P 2	0.0634		0.0559		0.0733		0.0710		0.0765		0.0694		0.0584		0.0515		0.0715	
	TR: P 3	0.0716		0.0659		0.0817		0.0783		0.0827		0.0734		0.0678		0.0606		0.0824	
	TR: P 4	0.0812		0.0768		0.0934		0.0874		0.0943		0.0793		0.0788		0.0708		0.0913	
	TR: P 5	0.0975		0.0956		0.1075		0.1019		0.1082		0.0877		0.0996		0.0874		0.1138	
	TR: P 5-1	0.0389	*	0.0480	*	0.0440	*	0.0348	*	0.0372	*	0.0210	*	0.0396	*	0.0407	*	0.0578	*
	t-stat	25.2141		13.5326		8.6987		5.9824		4.2123		6.2316		15.5095		16.0382		8.0765	
	DVOL: P 1	0.0657		0.0574		0.0748		0.0764		0.0766		0.0722		0.0634		0.0545		0.0627	
	DVOL: P 2	0.0649		0.0569		0.0731		0.0707		0.0778		0.0693		0.0640		0.0531		0.0705	
	DVOL: P 3	0.0665		0.0531		0.0712		0.0717		0.0794		0.0700		0.0661		0.0583		0.0816	
	DVOL: P 4	0.0671		0.0529		0.0698		0.0697		0.0766		0.0686		0.0709		0.0618		0.0795	
	DVOL: P 5	0.0612		0.0490		0.0551		0.0588		0.0747		0.0615		0.0666		0.0596		0.0769	
	DVOL: P 5-1	-0.0045	*	-0.0084	*	-0.0197	*	-0.0176	*	-0.0018		-0.0107	*	0.0032		0.0051	*	0.0142	*
	t-stat	*-3.3516*		*-3.5615*		*-5.1345*		*-3.3686*		*-0.2579*		*-3.4143*		*1.3232*		*2.0742*		*2.4535*	

Table 3.4 Mean of time-series monthly return of portfolios constructed by liquidity meaures

All the stocks are ranked on the basis of its monthly liquidity measures, in an ascending order. The portfolios are named by their liquidity measures, and the number in the names of portfolios indicates the rank of liquidity measures' quantity. e.g. in the groups of spread (S), P1 indicates the stocks in this portfolio have lowest spread; while in the groups of R/DVOL, the stocks in portfolio of P5 have the highest R/Dvol. The portfolios are monthly rebalanced, on the basis of month (t-1) liquidity measures, and we report the time-series average return of portfolios in month t. The returns of portfolios are calculated by equal-weighted. The data ranges from:1962 to 2011, where the whole sample horizon is divided into 8 sub-periods according to the Business Cylces, Jan 1962 to Dec. 1969, Jan 1970 to Nov 1973, Dec 1973 to Jan 1980, Feb 1980 to July 1981, Aug 1981 to July 1990, Aug 1990 to March 2001, April 2001 to Dec 2007, Jan 2008 to Dec 2011. The last row in each panel reports values for t-tests referring to the null hypothesis of no difference in means between P1 and P5. We use * to denote the significance of the difference at 5%.

Panel C	*liquidity portfolio*	whole horizon	period 1	period 2	period 3	period 4	period 5	period 6	period 7	period 8
	R/DVOL: P 1	0.0598	0.0475	0.0537	0.0573	0.0735	0.0604	0.0655	0.0578	0.0750
	R/DVOL: P 2	0.0676	0.0536	0.0679	0.0698	0.0791	0.0684	0.0702	0.0639	0.0841
	R/DVOL: P 3	0.0708	0.0572	0.0746	0.0741	0.0796	0.0730	0.0727	0.0636	0.0869
	R/DVOL: P 4	0.0723	0.0611	0.0795	0.0776	0.0819	0.0747	0.0747	0.0612	0.0824
	R/DVOL: P 5	0.0757	0.0645	0.0859	0.0835	0.0829	0.0776	0.0766	0.0682	0.0783
	R/DVOL: P 5-1	0.0159 *	0.0170 *	0.0322 *	0.0261 *	0.0094	0.0172 *	0.0111 *	0.0104 *	0.0033
	t-stat	11.4378	6.6299	7.0736	4.8806	1.2346	5.2758	4.2856	3.8782	1.5925
	R/TR: P 1	0.0775	0.0787	0.0890	0.0846	0.0927	0.0742	0.0725	0.0659	0.0882
	R/TR: P 2	0.0759	0.0741	0.0854	0.0822	0.0903	0.0748	0.0715	0.0650	0.0874
	R/TR: P 3	0.0740	0.0683	0.0839	0.0803	0.0874	0.0748	0.0714	0.0621	0.0859
	R/TR: P 4	0.0724	0.0635	0.0809	0.0789	0.0833	0.0755	0.0724	0.0607	0.0797
	R/TR: P 5	0.0731	0.0579	0.0809	0.0803	0.0795	0.0779	0.0775	0.0641	0.0742
	R/TR: P 5-1	-0.0045 *	-0.0208 *	-0.0081 *	-0.0042 *	-0.0132 *	0.0037	0.0050 *	-0.0018 *	-0.0140 *
	t-stat	*-3.1287*	*-6.6726*	*-1.7126*	*-1.7473*	*-1.7935*	*1.1218*	*2.1935*	*-1.7692*	*-2.3388*

Table 3.5 Cross-sctional regression

This table reports the cross-sectional regressions results. The data use in the cross-section regressions are from a sample of average 2050 NYSE-AMEX common listed firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. The dependent variables in the row are monthly individual asset excess return. The independent variables (first column) are liquidity measures, CAP, BM, EP, DY, RET23, RET 46, RET712 and 1/P, where CAP is the market capitalizations of firms, BM is the book-to-market ratio, obtained by the ratio of last year's book value to the market prices at the end of each month. EP is the earning-price ratio, calculated by the earnings over the prior year divided by the share prices at the end of each month. DY is the dividend yield, which is calculated by the sum of last year's dividend over the prices at the end of each month. Ret 23, Ret46, Ret712 are cumulative returns of over the second through third, fourth through sixth, and seventh through twelfth months prior to the present months, respectively. 1/P denotes the reciprocal of closing prices at the end of month. Each Panel reports results from one specific liquidity measure: S is the value of absolute monthly spreads, which are obtained by taking average of the daily absolute spread within each month, the results are in Panel A. RS represents relative spread, namely, the ratio of absolute spread to share closing prices, and the monthly relative spread is the average of daily relative spread, the results are in Panel B. DVOL denotes sum of daily dollar trading volumes within month for each stock, the results are in Panel C. TR is the monthly turnover ratio, calculated by monthly trading volume over number of shares outstanding in each month, the results are in Panel D. R/DVOL denotes the ratio of absolute return to dollar volume, while the monthly R/DVOL is the average daily R/DVOL, the results are in Panel E. R/TR is defined similar to the previous variable, but the absolute return is divided by daily turnover ratio, the results are in Panel F. The cross-sectional regression generate monthly coefficients for each independent variable The coefficients reported in the table are obtained by the time-series mean of monthly estimation results. The t-statistics are calculated by the time-series coefficients estimation; the results are displayed on the right hand of the coefficients estimation. All the results are demonstrated in 8 sub-periods (Period 1 to 8) and whole sample horizon (1990-2011 for Panel A and B, 1962-2011 for Panel C,D,E,F). We use * to denote the significance of the coefficients at 5%.

Panel A	Period 1		Period 2		Period 3		Period 4		Period 5		Period 6		Period 7		Period 8		whole period	
	Jan 1962 to Dec. 1969,		Jan 1970 to Nov 1973		Dec 1973 to Jan 1980		Feb 1980 to July 1981		Aug 1981 to July 1990		Aug 1990 to March 2001		April 2001 to Dec 2007		Jan 2008 to Dec 2011		whole period	
	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return
S											**0.000** *	**0.000** *	**0.002** *	**0.001** *	**-0.001**	**-0.008**	**0.000** *	**0.001** *
											2.342	1.857	1.909	1.011	-0.648	-0.448	1.940	1.765
CAP											**0.001**	**0.000**	**0.000**	**-0.001**	**-0.001** *	**-0.001** *	**0.000**	**0.000**
											1.045	1.055	-0.717	-0.206	-1.616	-1.886	-0.652	-0.536
BM											**0.000**	**0.000**	**0.001** *	**0.000** *	**-0.001**	**0.000**	**0.000**	**0.001**
											0.890	0.873	1.601	1.652	-0.858	-0.171	1.343	1.625
EP											**0.001**	**0.001**	**0.008** *	**0.008** *	**0.002**	**0.002**	**0.004** *	**0.001** *
											0.201	0.195	3.161	2.433	0.754	0.286	2.527	1.882
DY											**-0.003**	**0.010**	**-0.005**	**-0.598**	**0.007**	**0.009**	**-0.002**	**-0.005**
											-0.178	1.841	-0.267	-0.183	0.658	0.648	-0.225	-0.156
RET23											**-0.003**	**-0.009**	**0.009**	**0.006**	**-0.013**	**-0.077**	**-0.001**	**0.000**
											-0.515	0.469	1.187	1.367	-1.002	-1.633	-0.189	-0.714
RET46											**0.014** *	**0.503** *	**0.008**	**0.004**	**-0.009**	**-0.003**	**0.007**	**0.003** *
											3.328	2.816	1.481	1.745	-0.774	-0.237	3.070	2.136
RET712											**0.004**	**0.008**	**0.002**	**0.003**	**-0.006**	**-0.009**	**0.001**	**0.010** *
											1.363	1.606	0.460	0.874	-0.652	-0.834	0.739	2.277
1/P											**0.003** *	**0.002** *	**0.005** *	**0.008** *	**0.006** *	**0.004** *	**0.004** *	**0.002** *
											2.322	2.197	2.824	2.529	1.896	1.921	6.255	4.160

Table 3.5 Cross-sctional regression

This table reports the cross-sectional regressions results. The data use in the cross-section regressions are from a sample of average 2050 NYSE-AMEX common listed firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. The dependent variables in the row are monthly individual asset excess return. The independent variables (first column) are liquidity measures, CAP, BM, EP, DY, RET23, RET 46, RET712 and 1/P, where CAP is the market capitalizations of firms, BM is the book-to-market ratio, obtained by the ratio of last year's book value to the market prices at the end of each month. EP is the earning-price ratio, calculated by the earnings over the prior year divided by the share prices at the end of each month. DY is the dividend yield, which is calculated by the sum of last year's dividend over the prices at the end of each month. Ret 23, Ret46, Ret712 are cumulative returns of over the second through third, fourth through sixth, and seventh through twelfth months prior to the present months, respectively. 1/P denotes the reciprocal of closing prices at the end of month. Each Panel reports results from one specific liquidity measure: S is the value of absolute monthly spreads, which are obtained by taking average of the daily absolute spread within each month, the results are in Panel A. RS represents relative spread, namely, the ratio of absolute spread to share closing prices, and the monthly relative spread is the average of daily relative spread, the results are in Panel B. DVOL denotes sum of daily dollar trading volumes within month for each stock, the results are in Panel C. TR is the monthly turnover ratio, calculated by monthly trading volume over number of shares outstanding in each month, the results are in Panel D. R/DVOL denotes the ratio of absolute return to dollar volume, while the monthly R/DVOL is the average daily R/DVOL, the results are in Panel E. R/TR is defined similar to the previous variable, but the absolute return is divided by daily turnover ratio, the results are in Panel F. The cross-sectional regression generate monthly coefficients for each independent variable The coefficients reported in the table are obtained by the time-series mean of monthly estimation results. The t-statistics are calculated by the time-series coefficients estimation; the results are displayed on the right hand of the coefficients estimation. All the results are demonstrated in 8 sub-periods (Period 1 to 8) and whole sample horizon (1990-2011 for Panel A and B, 1962-2011 for Panel C,D,E,F). We use * to denote the significance of the coefficients at 5%.

Panel B	Period 1 Jan 1962 to Dec. 1969,		Period 2 Jan 1970 to Nov 1973		Period 3 Dec 1973 to Jan 1980		Period 4 Feb 1980 to July 1981		Period 5 Aug 1981 to July 1990		Period 6 Aug 1990 to March 2001		Period 7 April 2001 to Dec 2007		Period 8 Jan 2008 to Dec 2011		whole period whole period	
	excess return	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**
RS											**0.000** *	**0.000** *	**0.001** *	**0.005** *	**0.000**	**-0.001**	**0.000** *	**0.001** *
											1.630	1.783	1.707	1.910	-1.116	-1.038	1.988	1.762
CAP											**0.001**	**0.000**	**0.000**	**0.000**	**-0.002** *	**-0.007** *	**0.000**	**0.000**
											1.061	1.335	-0.709	-0.316	-1.855	-1.839	-0.842	-0.237
BM											**0.000**	**0.000**	**0.001** *	**0.001** *	**-0.001**	**0.000**	**0.000**	**0.000**
											0.818	0.570	1.657	1.803	-0.903	-0.383	1.271	1.470
EP											**0.002**	**0.002**	**0.008** *	**0.002** *	**0.002**	**0.002**	**0.004** *	**0.007** *
											0.397	0.908	3.529	2.212	0.769	0.856	2.893	1.835
DY											**-0.004**	**-0.009**	**-0.004**	**-0.009**	**0.008**	**0.002**	**-0.001**	**-0.004**
											-0.235	-0.700	-0.210	-0.958	0.733	0.897	-0.203	-0.503
RET23											**-0.003**	**-0.003**	**0.009**	**0.007**	**-0.013**	**-0.098** *	**-0.001**	**-0.006**
											-0.492	-0.823	1.179	1.105	-1.025	-1.775	-0.200	-0.174
RET46											**0.015** *	**0.026** *	**0.008**	**0.005**	**-0.009**	**-0.005**	**0.007** *	**0.004** *
											3.338	2.462	1.477	1.690	-0.786	-0.493	3.070	2.317
RET712											**0.004**	**0.005**	**0.001**	**0.002**	**-0.006**	**-0.007**	**0.001**	**0.004**
											1.288	1.426	0.414	0.717	-0.665	-0.686	0.630	0.204
1/P											**0.003** *	**0.009** *	**0.003** *	**0.002** *	**0.007** *	**0.005** *	**0.004** *	**0.009** *
											2.243	2.629	2.238	2.174	2.460	2.661	6.170	4.166

Table 3.5 Cross-sctional regression

This table reports the cross-sectional regressions results. The data use in the cross-section regressions are from a sample of average 2050 NYSE-AMEX common listed firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. The dependent variables in the row are monthly individual asset excess return. The independent variables (first column) are liquidity measures, CAP, BM, EP, DY, RET23, RET 46, RET712 and 1/P, where CAP is the market capitalizations of firms, BM is the book-to-market ratio, obtained by the ratio of last year's book value to the market prices at the end of each month. EP is the earning-price ratio, calculated by the earnings over the prior year divided by the share prices at the end of each month. DY is the dividend yield, which is calculated by the sum of last year's dividend over the prices at the end of each month. Ret 23, Ret46, Ret712 are cumulative returns of over the second through third, fourth through sixth, and seventh through twelfth months prior to the present months, respectively. 1/P denotes the reciprocal of closing prices at the end of month. Each Panel reports results from one specific liquidity measure: S is the value of absolute monthly spreads, which are obtained by taking average of the daily absolute spread within each month, the results are in Panel A. RS represents relative spread, namely, the ratio of absolute spread to share closing prices, and the monthly relative spread is the average of daily relative spread, the results are in Panel B. DVOL denotes sum of daily dollar trading volumes within month for each stock, the results are in Panel C. TR is the monthly turnover ratio, calculated by monthly trading volume over number of shares outstanding in each month, the results are in Panel D. R/DVOL denotes the ratio of absolute return to dollar volume, while the monthly R/DVOL is the average daily R/DVOL, the results are in Panel E. R/TR is defined similar to the previous variable, but the absolute return is divided by daily turnover ratio, the results are in Panel F. The cross-sectional regression generate monthly coefficients for each independent variable The coefficients reported in the table are obtained by the time-series mean of monthly estimation results. The t-statistics are calculated by the time-series coefficients estimation; the results are displayed on the right hand of the coefficients estimation. All the results are demonstrated in 8 sub-periods (Period 1 to 8) and whole sample horizon (1990-2011 for Panel A and B, 1962-2011 for Panel C,D,E,F). We use * to denote the significance of the coefficients at 5%.

Panel C	Period 1		Period 2		Period 3		Period 4		Period 5		Period 6		Period 7		Period 8		whole period	
	Jan 1962 to Dec. 1969,		Jan 1970 to Nov 1973		Dec 1973 to Jan 1980		Feb 1980 to July 1981		Aug 1981 to July 1990		Aug 1990 to March 2001		April 2001 to Dec 2007		Jan 2008 to Dec 2011		whole period	
	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return
DVOL	**0.001**	**0.000**	**-0.005 ***	**-0.002 ***	**-0.001**	**-0.009**	**-0.002**	**-0.009**	**-0.002 ***	**-0.001 ***	**0.000**	**0.000**	**-0.001**	**-0.001**	**0.000**	**0.000**	**-0.001 ***	**-0.001 ***
	0.439	0.504	-2.891	-1.878	-0.895	-0.170	-0.757	-0.717	-2.373	-2.569	0.360	0.368	-0.631	-0.267	-0.252	-0.252	-2.166	-2.438
CAP	**-0.002**	**-0.004**	**0.005 ***	**0.003 ***	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.004**	**0.000**	**0.000**	**0.000**	**-0.002**	**-0.001**	**0.000**	**0.000**	**0.001**
	-1.334	-1.363	2.174	1.776	-0.209	-0.246	0.091	0.019	1.304	1.598	0.242	0.655	-0.270	-0.682	-0.342	-0.309	0.594	0.442
BM	**0.000**	**0.001**	**0.001**	**0.007**	**0.004 ***	**0.001 ***	**0.001**	**0.000**	**0.001**	**0.003**	**0.000**	**0.000**	**0.001 ***	**0.001**	**-0.001**	**0.000**	**0.001 ***	**0.001 ***
	0.149	0.300	0.767	0.217	3.028	2.910	0.276	0.311	0.867	0.833	0.889	0.809	1.681	1.068	-0.806	-0.738	2.691	2.830
EP	**0.020 ***	**0.094 ***	**-0.037 ***	**-0.093 ***	**0.009**	**0.009**	**0.013**	**0.083 ***	**0.004**	**0.004**	**0.005**	**0.006 ***	**0.008 ***	**0.005 ***	**0.002**	**0.007**	**0.004**	**0.001**
	1.751	1.854	-1.978	-1.846	1.040	1.098	1.206	1.764	1.035	1.635	1.170	1.850	3.361	1.792	0.772	0.388	1.563	1.351
DY	**-0.080 ***	**-0.045 ***	**0.047**	**0.090**	**-0.110 ***	**-0.081**	**-0.058**	**-0.079**	**-0.002**	**-0.003**	**-0.006**	**-0.001**	**-0.003**	**-0.010**	**0.009**	**0.009**	**-0.024 ***	**-0.021 ***
	-2.538	-2.275	0.701	0.700	-2.712	-1.616	-1.460	-1.403	-0.133	-0.363	-0.393	-0.377	-0.145	-0.644	0.774	0.552	-2.343	-2.523
RET23	**0.028 ***	**0.060 ***	**0.013**	**0.064 ***	**0.006**	**0.008**	**0.004**	**0.006**	**0.003**	**0.007**	**-0.006**	**-0.007**	**0.011**	**0.016 ***	**-0.013**	**-0.040**	**0.005 ***	**0.002 ***
	3.888	1.661	1.434	1.796	0.991	0.359	0.229	0.312	0.476	0.979	-0.983	-0.700	1.512	1.917	-1.075	-1.409	2.049	2.830
RET46	**0.015 ***	**0.003 ***	**0.007**	**0.007**	**0.005**	**0.008**	**0.015**	**0.004**	**0.010 ***	**0.009 ***	**0.014 ***	**0.024 ***	**0.009 ***	**0.001 ***	**-0.008**	**-0.003**	**0.009 ***	**0.003 ***
	2.470	2.079	0.835	0.912	0.699	0.675	1.152	1.164	2.326	2.786	3.319	3.501	1.617	1.757	-0.774	-0.768	4.135	3.961
RET712	**0.011 ***	**0.011 ***	**0.002**	**0.001**	**0.010 ***	**0.021 ***	**0.012**	**0.065**	**0.005**	**0.006 ***	**0.008 ***	**0.005 ***	**0.002**	**0.003**	**-0.005**	**-0.004**	**0.006 ***	**0.007 ***
	3.677	3.300	0.499	0.731	2.677	1.974	0.886	0.046	1.416	1.727	2.361	1.830	0.567	0.695	-0.641	-0.985	3.767	2.445
1/P	**0.001**	**0.004**	**-0.002**	**-0.007**	**0.005 ***	**0.005 ***	**0.000**	**0.000**	**0.000**	**0.000**	**0.004 ***	**0.010 ***	**0.003 ***	**0.000 ***	**0.007 ***	**0.009 ***	**0.002 ***	**0.005 ***
	0.731	0.456	-0.763	-0.484	1.994	1.909	0.067	0.856	-0.297	-0.457	2.935	2.367	1.914	1.730	2.500	2.877	3.573	2.362

Table 3.5 Cross-sctional regression

This table reports the cross-sectional regressions results. The data use in the cross-section regressions are from a sample of average 2050 NYSE-AMEX common listed firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. The dependent variables in the row are monthly individual asset excess return. The independent variables (first column) are liquidity measures, CAP, BM, EP, DY, RET23, RET 46, RET712 and 1/P, where CAP is the market capitalizations of firms, BM is the book-to-market ratio, obtained by the ratio of last year's book value to the market prices at the end of each month. EP is the earning-price ratio, calculated by the earnings over the prior year divided by the share prices at the end of each month. DY is the dividend yield, which is calculated by the sum of last year's dividend over the prices at the end of each month. Ret 23, Ret46, Ret712 are cumulative returns of over the second through third, fourth through sixth, and seventh through twelfth months prior to the present months, respectively. 1/P denotes the reciprocal of closing prices at the end of month. Each Panel reports results from one specific liquidity measure: S is the value of absolute monthly spreads, which are obtained by taking average of the daily absolute spread within each month, the results are in Panel A. RS represents relative spread, namely, the ratio of absolute spread to share closing prices, and the monthly relative spread is the average of daily relative spread, the results are in Panel B. DVOL denotes sum of daily dollar trading volumes within month for each stock, the results are in Panel C. TR is the monthly turnover ratio, calculated by monthly trading volume over number of shares outstanding in each month, the results are in Panel D. R/DVOL denotes the ratio of absolute return to dollar volume, while the monthly R/DVOL is the average daily R/DVOL, the results are in Panel E. R/TR is defined similar to the previous variable, but the absolute return is divided by daily turnover ratio, the results are in Panel F. The cross-sectional regression generate monthly coefficients for each independent variable The coefficients reported in the table are obtained by the time-series mean of monthly estimation results. The t-statistics are calculated by the time-series coefficients estimation; the results are displayed on the right hand of the coefficients estimation. All the results are demonstrated in 8 sub-periods (Period 1 to 8) and whole sample horizon (1990-2011 for Panel A and B, 1962-2011 for Panel C,D,E,F). We use * to denote the significance of the coefficients at 5%.

Panel D	Period 1		Period 2		Period 3		Period 4		Period 5		Period 6		Period 7		Period 8		whole period	
	Jan 1962 to Dec. 1969,		Jan 1970 to Nov 1973		Dec 1973 to Jan 1980		Feb 1980 to July 1981		Aug 1981 to July 1990		Aug 1990 to March 2001		April 2001 to Dec 2007		Jan 2008 to Dec 2011		whole period	
	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return
TR	**0.001**	**0.001**	**-0.005 ***	**-0.002 ***	**-0.001**	**-0.006**	**-0.002**	**-0.003**	**-0.002 ***	**-0.003 ***	**0.000**	**0.001**	**-0.001**	**0.000**	**-0.001**	**-0.001**	**-0.001 ***	**0.000 ***
	0.449	0.805	-2.885	-2.414	-0.906	-0.844	-0.762	-0.273	-2.366	-2.446	0.318	0.138	-0.630	-0.451	-0.325	-0.287	-2.191 *	-2.669 *
CAP	**-0.001 ***	**-0.005 ***	**-0.001**	**0.000**	**-0.001 ***	**-0.004 ***	**-0.002**	**-0.003**	**0.000**	**-0.001**	**0.001**	**0.000**	**-0.001 ***	**-0.001 ***	**-0.001 ***	**-0.003 ***	**-0.001 ***	**0.000 ***
	-2.248	-2.128	-0.521	-0.430	-1.900	-1.717	-0.992	-0.280	-0.656	-0.529	0.960	0.191	-1.811	-1.924	-1.638	-1.756	-2.472 *	-2.760 *
BM	**0.000**	**0.001**	**0.001**	**0.001**	**0.004 ***	**0.006 ***	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**	**0.001**	**0.001 ***	**0.000 ***	**-0.001**	**0.000**	**0.001 ***	**0.000 ***
	0.150	0.654	0.763	0.736	3.031	2.582	0.273	0.616	0.863	0.480	0.869	0.821	1.666	1.799	-0.863	-0.155	2.669 *	2.947 *
EP	**0.020 ***	**0.076 ***	**-0.037 ***	**-0.035 ***	**0.009**	**0.008**	**0.013**	**0.076 ***	**0.004**	**0.008**	**0.005**	**0.006**	**0.008 ***	**0.004 ***	**0.002**	**0.000**	**0.004 ***	**0.002 ***
	1.748	1.771	-1.974	-1.853	1.039	1.031	1.208	1.794	1.041	1.542	1.171	1.481	3.357	1.756	0.781	0.978	1.563 *	1.901 *
DY	**-0.080 ***	**-0.077 ***	**0.048**	**0.045**	**-0.110 ***	**-0.281 ***	**-0.058**	**-0.072**	**-0.002**	**-0.008**	**-0.006**	**-0.008**	**-0.003**	**-0.005**	**0.007**	**0.003**	**-0.024 ***	**-0.090 ***
	-2.536	-2.510	0.702	0.328	-2.712	-2.630	-1.454	-1.559	-0.132	-0.688	-0.404	-0.709	-0.147	-0.538	0.658	0.775	-2.360 *	-2.964 *
RET23	**0.028 ***	**0.036 ***	**0.013**	**0.035 ***	**0.006**	**0.008**	**0.004**	**0.003**	**0.003**	**0.009**	**-0.006**	**-0.010**	**0.011**	**0.022 ***	**-0.013**	**-0.076 ***	**0.005 ***	**0.001 ***
	3.886	2.227	1.437	1.803	0.988	0.907	0.227	0.342	0.474	0.789	-0.980	-0.746	1.512	1.946	-1.077	-1.901	2.046 *	2.117 *
RET46	**0.015 ***	**0.010 ***	**0.007**	**0.002**	**0.005**	**0.000**	**0.015**	**0.049 ***	**0.010 ***	**0.068 ***	**0.014 ***	**0.079 ***	**0.009 ***	**0.008 ***	**-0.009**	**-0.007**	**0.009 ***	**0.001 ***
	2.472	2.879	0.836	0.851	0.694	0.746	1.151	1.720	2.324	2.610	3.334	2.403	1.616	1.659	-0.795	-0.229	4.134 *	3.254 *
RET712	**0.011 ***	**0.011 ***	**0.002**	**0.006**	**0.010 ***	**0.082 ***	**0.012**	**0.040**	**0.005**	**0.003**	**0.008 ***	**0.009 ***	**0.002**	**0.007**	**-0.005**	**-0.009**	**0.006 ***	**0.007 ***
	3.686	2.698	0.499	0.247	2.680	2.708	0.885	0.893	1.416	1.514	2.364	2.464	0.582	0.800	-0.615	-0.646	3.788 *	3.083 *
1/P	**0.001**	**0.010**	**-0.002**	**-0.005**	**0.005 ***	**0.009 ***	**0.000**	**0.000**	**0.000**	**-0.001**	**0.004 ***	**0.004 ***	**0.003 ***	**0.003 ***	**0.007 ***	**0.002 ***	**0.002 ***	**0.008 ***
	0.732	0.417	-0.765	-0.422	1.992	1.996	0.068	0.013	-0.294	-0.226	2.917	2.398	1.893	1.941	2.472	2.434	3.550 *	2.340 *

Table 3.5 Cross-sctional regression

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	Period 1		**Period 2**		**Period 3**		**Period 4**		**Period 5**		**Period 6**		**Period 7**		**Period 8**		**whole period**	
Panel E	**Jan 1962 to Dec. 1969,**		**Jan 1970 to Nov 1973**		**Dec 1973 to Jan 1980**		**Feb 1980 to July 1981**		**Aug 1981 to July 1990**		**Aug 1990 to March 2001**		**April 2001 to Dec 2007**		**Jan 2008 to Dec 2011**		**whole period**	
	excess return	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**	**excess return**	**adjusted return**
R/DVOL	**0.005 ***	**0.008 ***	**0.001**	**0.000**	**0.002**	**0.004**	**0.001 ***	**0.005 ***	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	**0.001 ***	**0.001 ***	**0.000 ***	**0.001 ***
	3.039	2.227	0.754	0.801	1.049	1.020	2.564	2.851	-0.633	-0.735	1.000	1.322	-0.038	-0.022	2.073	2.846	1.701	1.831
CAP	**0.005 ***	**0.008 ***	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**-0.001**	**-0.003**	**0.000**	**0.001**	**0.000**	**-0.001**
	2.840	1.936	-0.285	-0.068	0.108	0.351	1.068	1.385	0.287	0.175	-0.193	-0.194	-0.849	-0.711	0.458	0.686	-0.605	-0.421
BM	**0.001**	**0.000**	**0.004 ***	**0.008 ***	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001 ***	**0.000 ***	**-0.001**	**-0.001**	**0.001 ***	**0.000 ***	**0.001 ***	**0.000 ***
	0.642	0.021	3.091	3.475	0.259	0.203	0.775	0.025	0.876	0.879	1.638	1.596	-0.833	-0.801	2.682	2.636	2.366	2.918
EP	**-0.049 ***	**-0.051 ***	**0.008**	**0.007**	**0.012**	**0.040**	**0.004**	**0.002 ***	**0.005**	**0.009**	**0.008 ***	**0.008 ***	**0.002**	**0.004**	**0.004**	**0.008**	**0.006 ***	**0.006 ***
	-2.740	-2.807	0.839	0.787	1.138	1.123	1.067	1.993	1.146	1.682	3.366	3.105	0.700	0.223	1.355	1.418	2.112	2.752
DY	**0.144 ***	**0.204 ***	**-0.099 ***	**-0.066 ***	**-0.054**	**-0.003**	**0.001**	**0.000**	**-0.007**	**-0.004**	**-0.002**	**-0.008**	**0.008**	**0.008**	**-0.016**	**-0.024**	**-0.024 ***	**-0.082 ***
	2.452	2.584		-1.885	-1.179	-1.044	0.034	0.059	-0.401	-0.475	-0.098	-0.025	0.677	0.819	-1.435	-1.220	-2.524	-2.047
RET23	**0.011**	**0.009**	**0.008**	**0.007 ***	**0.001**	**0.008**	**0.002**	**0.008**	**-0.006**	**-0.003 ***	**0.010**	**0.033**	**-0.013**	**-0.012**	**0.005 ***	**0.009 ***	**0.002**	**0.001**
	1.181	1.670	1.270	1.766	0.089	0.047	0.380	0.675	-1.123	-1.764	1.324	1.259	-1.060	-1.652	1.937	1.831	0.823	0.888
RET46	**0.006**	**0.008**	**0.007**	**0.005**	**0.013**	**0.058**	**0.011 ***	**0.073 ***	**0.014 ***	**0.033 ***	**0.009 ***	**0.008 ***	**-0.009**	**-0.002**	**0.009 ***	**0.006 ***	**0.000**	**-0.001**
	0.671	0.969	0.975	0.167	0.970	0.628	2.346	2.501	3.262	1.994	1.542	1.917	-0.817	-0.870	4.072	2.892	-0.150	-0.682
RET712	**0.001**	**0.000**	**0.010 ***	**0.001 ***	**0.011**	**0.011**	**0.006**	**0.003**	**0.008 ***	**0.008 ***	**0.002**	**0.002**	**-0.006**	**-0.004**	**0.006 ***	**0.010 ***	**-0.001**	**0.000**
	0.241	0.595	2.531	1.985	0.774	0.670	1.507	1.801	2.313	2.037	0.478	0.537	-0.662	-0.314	3.616	3.854	-0.746	-0.961
1/P	**-0.002**	**-0.006**	**0.006 ***	**0.002 ***	**0.000**	**0.000**	**-0.001**	**0.000**	**0.004 ***	**0.005 ***	**0.003 ***	**0.005 ***	**0.007 ***	**0.003 ***	**0.003 ***	**0.009 ***	**0.001 ***	**0.006 ***
	-0.599	-0.231	2.075	2.484	0.099	0.071	-0.603	-0.503	2.940	2.031	1.885	1.853	2.423	2.703	3.616	2.415	1.825	1.869

Table 3.5 Cross-sctional regression

This table reports the cross-sectional regressions results. The data use in the cross-section regressions are from a sample of average 2050 NYSE-AMEX common listed firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. The dependent variables in the row are monthly individual asset excess return. The independent variables (first column) are liquidity measures, CAP, BM, EP, DY, RET23, RET 46, RET712 and 1/P, where CAP is the market capitalizations of firms, BM is the book-to-market ratio, obtained by the ratio of last year's book value to the market prices at the end of each month. EP is the earning-price ratio, calculated by the earnings over the prior year divided by the share prices at the end of each month. DY is the dividend yield, which is calculated by the sum of last year's dividend over the prices at the end of each month. Ret 23, Ret46, Ret712 are cumulative returns of over the second through third, fourth through sixth, and seventh through twelfth months prior to the present months, respectively. 1/P denotes the reciprocal of closing prices at the end of month. Each Panel reports results from one specific liquidity measure: S is the value of absolute monthly spreads, which are obtained by taking average of the daily absolute spread within each month, the results are in Panel A. RS represents relative spread, namely, the ratio of absolute spread to share closing prices, and the monthly relative spread is the average of daily relative spread, the results are in Panel B. DVOL denotes sum of daily dollar trading volumes within month for each stock, the results are in Panel C. TR is the monthly turnover ratio, calculated by monthly trading volume over number of shares outstanding in each month, the results are in Panel D. R/DVOL denotes the ratio of absolute return to dollar volume, while the monthly R/DVOL is the average daily R/DVOL, the results are in Panel E. R/TR is defined similar to the previous variable, but the absolute return is divided by daily turnover ratio, the results are in Panel F. The cross-sectional regression generate monthly coefficients for each independent variable The coefficients reported in the table are obtained by the time-series mean of monthly estimation results. The t-statistics are calculated by the time-series coefficients estimation; the results are displayed on the right hand of the coefficients estimation. All the results are demonstrated in 8 sub-periods (Period 1 to 8) and whole sample horizon (1990-2011 for Panel A and B, 1962-2011 for Panel C,D,E,F). We use * to denote the significance of the coefficients at 5%.

Panel F	Period 1 Jan 1962 to Dec. 1969,		Period 2 Jan 1970 to Nov 1973		Period 3 Dec 1973 to Jan 1980		Period 4 Feb 1980 to July 1981		Period 5 Aug 1981 to July 1990		Period 6 Aug 1990 to March 2001		Period 7 April 2001 to Dec 2007		Period 8 Jan 2008 to Dec 2011		whole period whole period	
	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return	excess return	adjusted return
R/TR	**-0.001**	**-0.001**	**0.006 ***	**0.008 ***	**0.001**	**0.001**	**0.002**	**0.001**	**0.002 ***	**0.003 ***	**-0.001**	**0.000**	**0.001**	**0.001 ***	**0.000**	**0.000**	**0.001 ***	**0.000 ***
	-0.526	-0.298	4.364	3.471	1.225	1.326	0.980	0.530	2.674	2.284	-0.780	-0.635	1.161	1.917	0.070	0.054	2.388	2.967
CAP	**-0.001 ***	**-0.006 ***	**0.001**	**0.009**	**-0.002 ***	**-0.008 ***	**-0.002**	**-0.002**	**0.000**	**0.000**	**0.001**	**0.001**	**-0.001 ***	**-0.001 ***	**-0.001**	**0.000**	**-0.001 ***	**-0.001 ***
	-2.144	-2.734	1.031	1.269	-2.302	-2.388	-1.135	-1.380	-0.230	-0.197	0.882	0.838	-1.687	-1.384	-1.415	-1.361	-2.021	-2.731
BM	**0.000**	**0.000**	**0.002**	**0.007**	**0.004 ***	**0.007 ***	**0.004**	**0.008**	**0.001**	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**	**-0.001**	**0.000**	**0.001 ***	**0.002 ***
	0.121	0.441	1.337	1.405	2.868	2.199	1.566	1.576	1.030	1.086	0.838	0.018	1.582	1.311	-0.649	-0.512	3.098	2.825
EP	**0.021 ***	**0.029 ***	**-0.057 ***	**-0.032 ***	**0.017 ***	**0.045 ***	**0.005**	**0.008**	**0.007 ***	**0.009 ***	**0.008 ***	**0.006**	**0.008 ***	**0.002 ***	**0.002**	**0.002**	**0.006 ***	**0.002 ***
	1.699	1.849	-2.741	-2.803	1.862	1.952	0.412	0.587	1.651	1.129	1.947	1.571	3.542	2.938	0.668	0.750	2.068	2.293
DY	**-0.085 ***	**-0.090 ***	**0.040**	**0.065**	**-0.130 ***	**-0.069 ***	**-0.061**	**-0.099**	**-0.004**	**-0.001**	**-0.008**	**-0.006**	**-0.002**	**-0.010**	**0.010**	**0.005**	**-0.030 ***	**-0.100 ***
	-2.310	-2.141	0.483	0.445	-3.033	-2.001	-1.366	-1.642	-0.214	-0.215	-0.453	-0.966	-0.118	-0.143	0.836	0.823	-2.573	-2.180
RET23	**0.024 ***	**0.095 ***	**0.026 ***	**0.069 ***	**0.008**	**0.000**	**0.022**	**0.025**	**0.002**	**0.004**	**-0.002**	**-0.007**	**0.014 ***	**0.038 ***	**-0.013**	**-0.029**	**0.008 ***	**0.003 ***
	3.214	3.334	3.862	3.870	1.415	1.970	1.347	1.187	0.272	0.757	-0.262	-0.380	1.944	1.773	-1.061	-1.459	2.815	2.148
RET46	**0.011 ***	**0.030 ***	**0.023 ***	**0.020 ***	**0.010**	**0.007**	**0.006**	**0.010**	**0.010 ***	**0.100 ***	**0.015 ***	**0.077 ***	**0.011 ***	**0.072 ***	**-0.011**	**-0.100**	**0.010 ***	**0.060 ***
	1.766	1.839	3.253	2.701	1.461	1.274	0.530	0.212	2.262	2.668	3.693	1.973	2.030	2.340	-0.953	-0.099	4.522	2.550
RET712	**0.010 ***	**0.069 ***	**0.002**	**0.009**	**0.013 ***	**0.044 ***	**0.024 ***	**0.067**	**0.008 ***	**0.006 ***	**0.006 ***	**0.005 ***	**0.002**	**0.007**	**-0.006**	**-0.003**	**0.006 ***	**0.002 ***
	3.139	2.893	0.492	0.813	3.439	2.785	1.789	1.428	2.003	2.822	1.891	1.894	0.644	0.665	-0.743	-0.417	3.930	2.727
1/P	**0.001**	**0.002**	**-0.003**	**-0.009**	**0.002**	**0.003**	**0.000**	**0.001**	**0.000**	**0.000**	**0.004 ***	**0.008 ***	**0.003 ***	**0.099**	**0.007 ***	**0.008 ***	**0.002 ***	**0.009 ***
	0.556	0.855	-1.362	-1.233	1.088	1.625	0.101	0.953	-0.041	-0.050	3.134	3.384	1.641	1.411	2.451	2.224	3.265	2.471

Table 3.6 Contemporaneous correlation and Granger causality tests between VAR innovations

This table reports the contemporaneous correlation and granger causaliy tests results between the listed variables of interest. The market variables are aggregated by the all the avaiable assets in the daily data sample. Except spread and relative spread are only avaiable after 1990, other variables are available over 1962 to 2011. In Panel A, the first six variables are market-wide liquidity measures process, where MDVOL is market dollar volume, the sum of all available share dollar volume in each trading day. MS is the market spread, calculated by the average of cross-sectional shares spread on daily basis. MRS is the market relative spread, calculated by the average of cross-sectional shares relative spread on daily basis. MTR indicates market turnover ratio, obtained by value-weighted average of assets turnover ratio. MR/DVOL and MR/TR denote the market return to dollar volume and market return to turnover ratio, respectively, and they are derived from daily average of return to dollar volume and return to turnover ratio.MRET denotes the market return, which are calculated by the value-weighted daily return of shares. PRET and NRET are decomposed from MRET into the positive and negative strings, namely, positive return process are max (0, MRET), while negative return process are min (0, MRET). VOl is the volatility of market return, calculated by (MRET)^2. Ret23, Ret46, Ret712 are cumulative market returns of over the second through third, forth through sixth, and seventh through twelfith months prior to the present months, respectively. Note, we assume 22 trading days in one month. The matrix in Panel A demonstrates the contemporaneous correaltion between each pair of market variable processes. The pair wise correlation coefficients are in the intersections of the variables in row and in column. In Panel B, the results from Granger Causality tests are reported. Since it requires stationary process in Granger Causality tests, the non-staionary price-related variables, MDVOL, MTR, MS and MRS, are transformed by first difference. diff(xt) = xt - x(t-1). The p-value in matrix indicats the possibility of each variable in row does not granger cause the corresponding variable in column. The p-value lower than 0.1 are indicated by *. Panel C is equivalent to the results in Panel B.The resluts of REJECT to the bull hypothsis is according to the p-values in Panle B.

Panel A: Corrlation	**MDVOL**	**MS**	**MRS**	**MR/DVOL**	**MR/TR**	**MTR**	**VOL**	**RET**	**PRET**	**NRET**	**RET23**	**RET46**	**RET712**
MDVOL	1.00												
MS	-0.77 *	1.00											
MRS	-0.79 *	0.98 *	1.00										
MR/DVOL	-0.66 *	0.76 *	0.81 *	1.00									
MR/TR	-0.70 *	0.83 *	0.86 *	0.97 *	1.00								
MTR	0.95 *	-0.66 *	-0.67 *	-0.69 *	-0.72 *	1.00							
VOL	0.16 *	-0.08	-0.07	-0.02	0.01	0.25 *	1.00						
MRET	0.00	0.01	0.01	-0.04	-0.05	0.01	-0.06	1.00					
PRET	0.15 *	-0.07	-0.07	-0.04	-0.02	0.21 *	0.40 *	0.80 *	1.00				
NRET	-0.14 *	0.08	0.08	-0.02	-0.06	-0.20 *	-0.50 *	0.80 *	0.28	1.00			
RET23	0.00	0.06	0.05	-0.12 *	-0.14 *	0.01	-0.04	-0.01	-0.04	0.03	1.00		
RET46	0.02	0.05	0.04	-0.15 *	-0.16 *	0.00	-0.05	0.00	-0.04	0.04	-0.01	1.00	
RET712	0.05	0.12 *	0.09	-0.21 *	-0.20 *	0.02	-0.04	-0.01	-0.04	0.03	-0.07	0.38 *	1.00

Table 3.6 Contemporaneous correlation and Granger causality tests between VAR innovations

This table reports the contemporaneous correlation and granger causaliy tests results between the listed variables of interest. The market variables are aggregated by the all the avaiable assets in the daily data sample. Except spread and relative spread are only avaiable after 1990, other variables are available over 1962 to 2011. In Panel A, the first six variables are market-wide liquidity measures process, where MDVOL is market dollar volume, the sum of all available share dollar volume in each trading day. MS is the market spread, calculated by the average of cross-sectional shares spread on daily basis. MRS is the market relative spread, calculated by the average of cross-sectional shares relative spread on daily basis. MTR indicates market turnover ratio, obtained by value-weighted average of assets turnover ratio. MR/DVOL and MR/TR denote the market return to dollar volume and market return to turnover ratio, respectively, and they are derived from daily average of return to dollar volume and return to turnover ratio.MRET denotes the market return, which are calculated by the value-weighted daily return of shares. PRET and NRET are decomposed from MRET into the positive and negative strings, namely, positive return process are max (0, MRET), while negative return process are min (0, MRET). VOl is the volatility of market return, calculated by (MRET)^2. Ret23, Ret46, Ret712 are cumulative market returns of over the second through third, forth through sixth, and seventh through twelfith months prior to the present months, respectively. Note, we assume 22 trading days in one month. The matrix in Panel A demonstrates the contemporaneous correaltion between each pair of market variable processes. The pair wise correlation coefficients are in the intersections of the variables in row and in column. In Panel B, the results from Granger Causality tests are reported. Since it requires stationary process in Granger Causality tests, the non-staionary price-related variables, MDVOL, MTR, MS and MRS, are transformed by first difference. diff(xt) = xt - x(t-1). The p-value in matrix indicats the possibility of each variable in row does not granger cause the corresponding variable in column. The p-value lower than 0.1 are indicated by *. Panel C is equivalent to the results in Panel B.The resluts of REJECT to the bull hypothsis is according to the p-values in Panle B.

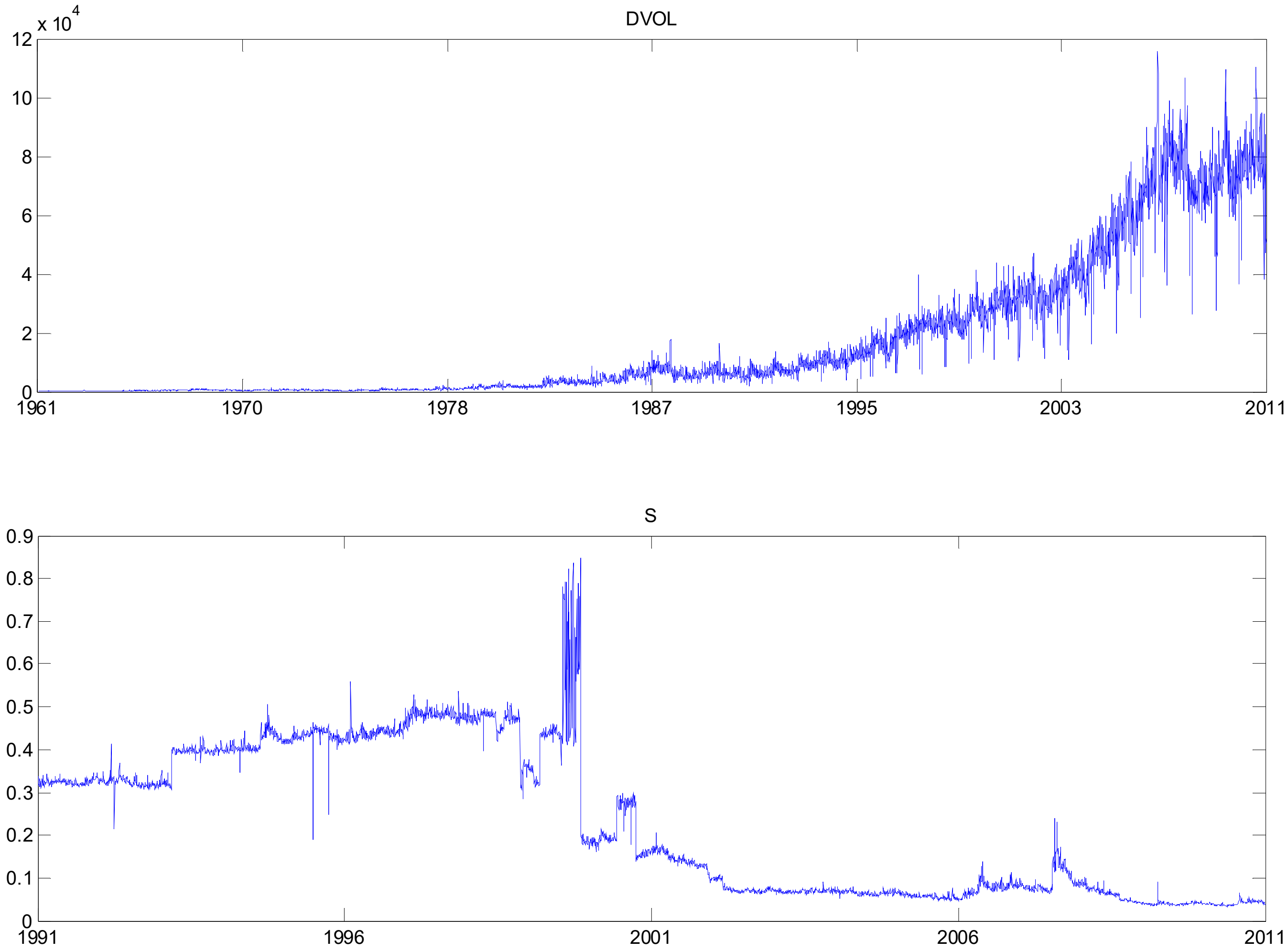
Panel B: p value	**MDVOL**	**MS**	**MRS**	**MTR**	**R/DVOL**	**MR/TR**	**VOL**	**RET**	**PRET**	**NRET**	**RET23**	**RET46**	**RET712**
MDVOL		0.555	0.000 *	0.000 *	1.000	0.884	0.000 *	0.000 *	0.000 *	0.000 *	0.001 *	0.154	0.244
MS	0.616		0.000 *	0.402	0.365	0.191	0.983	0.150	0.262	0.239	0.640	0.904	0.378
MRS	0.659	0.000 *		0.534	0.026 *	0.035 *	0.576	0.021 *	0.005 *	0.351	0.732	0.922	0.327
MTR	0.000 *	0.054 *	0.000 *		0.788	0.077	0.000 *	0.000 *	0.000 *	0.000 *	0.000 *	0.055 *	0.006 *
MR/DVOL	0.000 *	0.022 *	0.000 *	0.000 *		0.000 *	0.000 *	0.000 *	0.000 *	0.000 *	0.180	0.452	0.635
MR/TR	0.000 *	0.000 *	0.000 *	0.000 *	0.000 *		0.000 *	0.000 *	0.000 *	0.000 *	0.046 *	0.164	0.362
VOL	0.000 *	0.000 *	0.000 *	0.000 *	0.007 *	0.000 *		0.000 *	0.000 *	0.000 *	0.015 *	0.007 *	0.405
RET	0.000 *	0.002 *	0.000 *	0.010 *	0.079 *	0.036 *	0.000 *		0.000 *	0.000 *	0.010 *	0.005 *	0.016 *
PRET	0.000 *	0.001 *	0.000 *	0.000 *	0.000 *	0.000 *	0.000 *	0.000 *		0.000 *	0.004 *	0.000 *	0.014 *
NRET	0.000 *	0.003 *	0.000 *	0.000 *	0.011 *	0.010 *	0.000 *	0.000 *	0.000 *		0.007 *	0.056 *	0.476
RET23	0.776	0.443	0.379	0.159	0.000 *	0.000 *	0.000 *	0.000 *	0.000 *	0.000 *		0.236 *	0.000 *
RET46	0.000 *	0.514	0.410	0.000 *	0.599	0.207	0.006 *	0.078	0.009 *	0.122	0.011 *		0.000 *
RET712	0.004 *	0.332	0.757	0.001 *	0.629	0.114	0.053	0.723	0.103	0.263	0.104	0.000 *	

Table 3.6 Contemporaneous correlation and Granger causality tests between VAR innovations

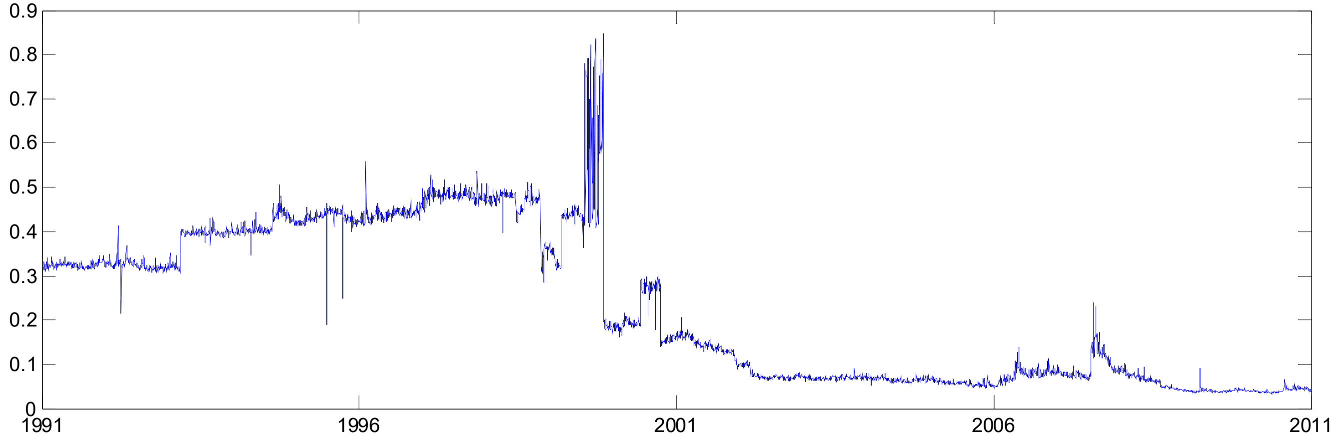
This table reports the contemporaneous correlation and granger causaliy tests results between the listed variables of interest. The market variables are aggregated by the all the avaiable assets in the daily data sample. Except spread and relative spread are only avaiable after 1990, other variables are available over 1962 to 2011. In Panel A, the first six variables are market-wide liquidity measures process, where MDVOL is market dollar volume, the sum of all available share dollar volume in each trading day. MS is the market spread, calculated by the average of cross-sectional shares spread on daily basis. MRS is the market relative spread, calculated by the average of cross-sectional shares relative spread on daily basis. MTR indicates market turnover ratio, obtained by value-weighted average of assets turnover ratio. MR/DVOL and MR/TR denote the market return to dollar volume and market return to turnover ratio, respectively, and they are derived from daily average of return to dollar volume and return to turnover ratio.MRET denotes the market return, which are calculated by the value-weighted daily return of shares. PRET and NRET are decomposed from MRET into the positive and negative strings, namely, positive return process are max (0, MRET), while negative return process are min (0, MRET). VOl is the volatility of market return, calculated by (MRET)^2. Ret23, Ret46, Ret712 are cumulative market returns of over the second through third, forth through sixth, and seventh through twelfith months prior to the present months, respectively. Note, we assume 22 trading days in one month. The matrix in Panel A demonstrates the contemporaneous correaltion between each pair of market variable processes. The pair wise correlation coefficients are in the intersections of the variables in row and in column. In Panel B, the results from Granger Causality tests are reported. Since it requires stationary process in Granger Causality tests, the non-staionary price-related variables, MDVOL, MTR, MS and MRS, are transformed by first difference. diff(xt) = xt - x(t-1). The p-value in matrix indicats the possibility of each variable in row does not granger cause the corresponding variable in column. The p-value lower than 0.1 are indicated by *. Panel C is equivalent to the results in Panel B.The resluts of REJECT to the bull hypothsis is according to the p-values in Panle B.

Panel C: Gausality	MDVOL	MS	MRS	MTR	MR/DVOL	MR/TR	VOL	RET	PRET	NRET	RET23	RET46	RET712
Ho, MDVOL do not Granger cause				REJECT	REJECT	REJECT	REJECT	REJECT	REJECT	REJECT		REJECT	REJECT
Ho, MS do not Granger cause		REJECT	REJECT	REJECT	REJECT	REJECT	REJECT	REJECT	REJECT	REJECT			
Ho, MRS do not Granger cause	REJECT	REJECT		REJECT	REJECT	REJECT	REJECT	REJECT	REJECT	REJECT			
Ho, MTR do not Granger cause	REJECT				REJECT	REJECT	REJECT	REJECT	REJECT	REJECT		REJECT	REJECT
Ho, MR/DVOL do not Granger cause			REJECT			REJECT	REJECT	REJECT	REJECT	REJECT	REJECT		
Ho, MR/TR do not Granger cause			REJECT		REJECT		REJECT	REJECT	REJECT	REJECT	REJECT		
Ho, VOL do not Granger cause	REJECT			REJECT	REJECT	REJECT		REJECT	REJECT	REJECT	REJECT	REJECT	
Ho, RET do not Granger cause	REJECT		REJECT	REJECT	REJECT	REJECT	REJECT		REJECT	REJECT	REJECT		
Ho, PRET do not Granger cause	REJECT		REJECT	REJECT	REJECT	REJECT	REJECT	REJECT		REJECT	REJECT	REJECT	
Ho, NRET do not Granger cause	REJECT			REJECT	REJECT	REJECT	REJECT	REJECT	REJECT		REJECT		
Ho, RET23 do not Granger cause	REJECT			REJECT		REJECT	REJECT	REJECT	REJECT	REJECT		REJECT	
Ho, RET46 do not Granger cause				REJECT			REJECT	REJECT	REJECT	REJECT			REJECT
Ho, RET712 do not Granger cause				REJECT				REJECT	REJECT		REJECT	REJECT	

Figure 3.1 The time-series plots of market-wide liquidity on daily basis.



RS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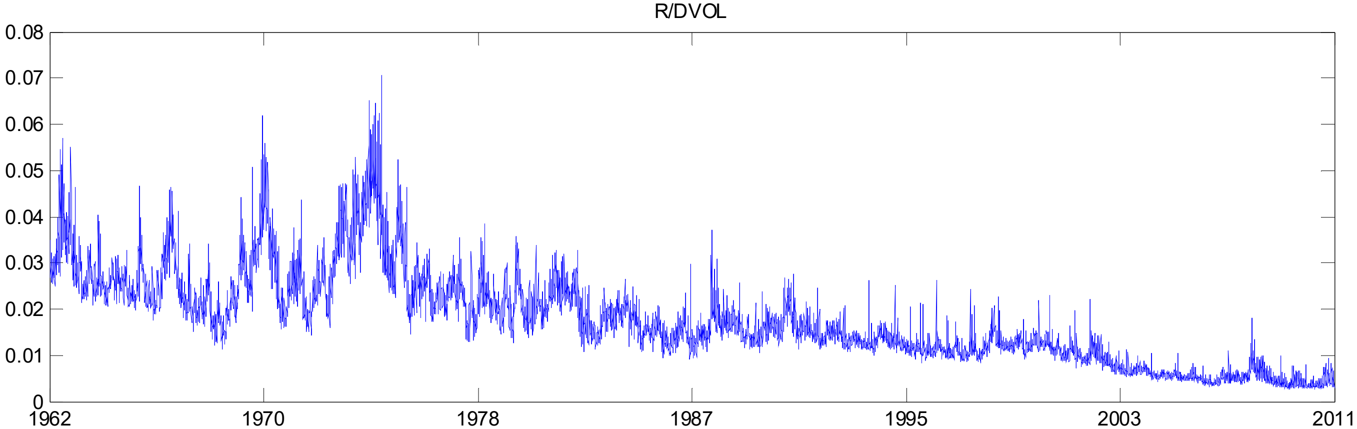
1991
1996
2001
2006
2011

R/DVOL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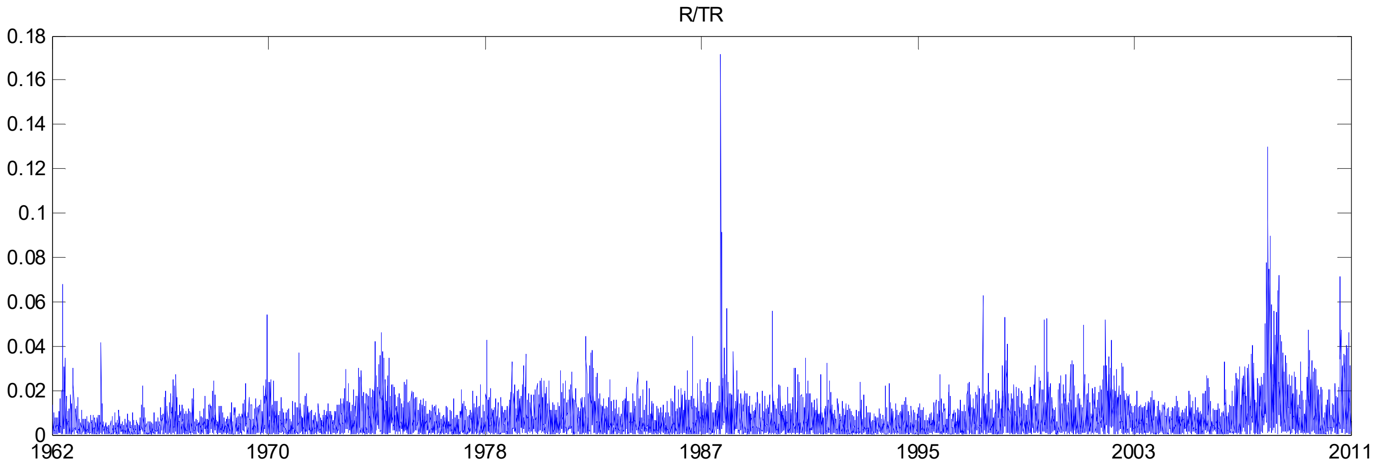
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1962
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1978
1987
1995
2003
2011

Figure 3.2 The Granger causality between three dimensions of liquidity measure at the market level. The arrows represent the causality between measures.

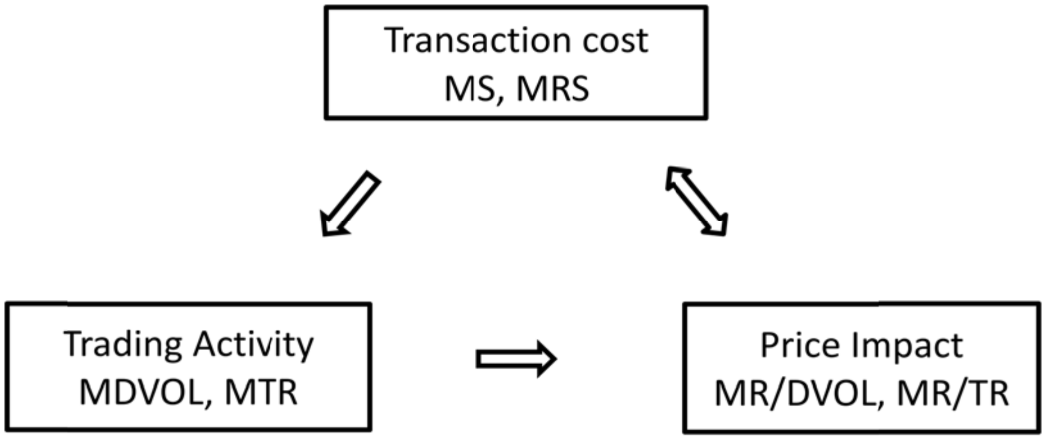
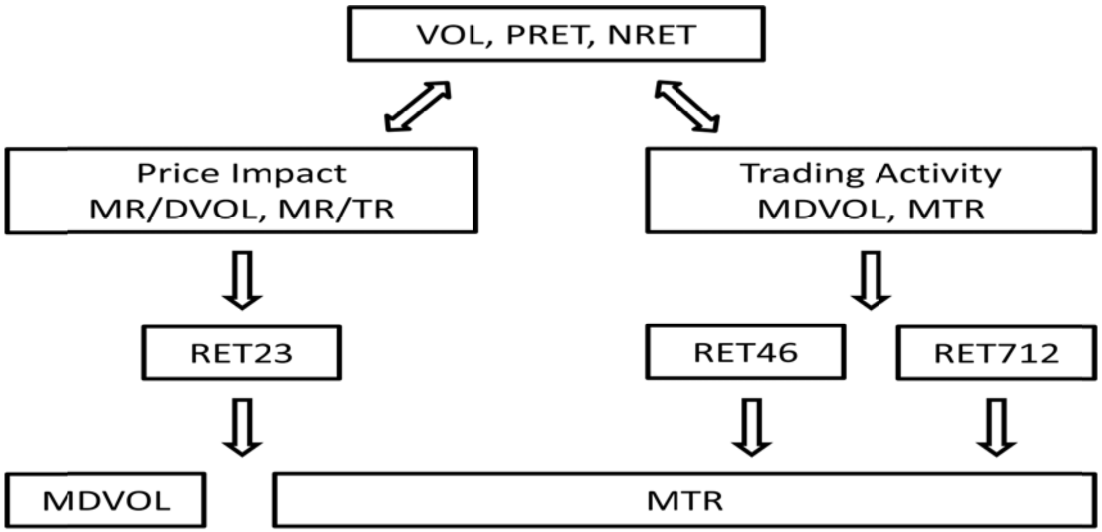


Figure 3.3 The Granger causality between the market indicators and three dimensions of liquidity measure at the market level. The arrows represent the causality between variables.



Chapter 4

The Investigation of Volatility of Liquidity

Abstract

Most of the empirical and theoretical work on liquidity and asset pricing focuses on the determination and quantification of the liquidity risk premium. The last decade, however, the interest of many researchers has been attracted by the volatility of liquidity risk premium. A negative relationship has been observed and discussed, in literature, between risk of trading activity and asset returns, and is attributed mostly to the clientele effect by Merton (1979). This thesis extends this finding and provides a comparative analysis of the volatility of liquidity risk through an asset pricing framework considering several dimensions of liquidity, such as transaction cost, trading activity and price impact. The empirical findings, consistent with the literature, provide evidence of heterogeneity across various liquidity components and volatility specifications. In addition, by extracting the commonality of volatility of liquidity across individual assets via principal component analysis, the systematic components of volatility of liquidity are examined accordingly.

Finally, a mimicking portfolio is constructed and used to track the systematic risk of volatility of liquidity, furnishing evidence that the latter is priced in asset returns.

4.1 Introduction

Liquidity is a set of characteristics that comprise a factor associated with, but not limited to, the transaction cost, the trading activity and the price impact.

In the study of the transaction cost, it is presumed that rational investors' preferences lie within liquid assets and thus their expectations about liquidity are priced through the demand and supply forces and consequently form the bid and ask quotes. Using the bid-ask spread (spread (S) and relative spread (RS)) as a proxy of the transaction cost, Amihud and Mendelson (1986) argue that the pricing mechanism is even more complicated due to the heterogeneity of the market participants' informational content. This informational asymmetry imposes a premium or a discount on securities' prices as a signal of good and bad news resulting from the excess demand (liquid) or supply (illiquid) of securities, respectively.

The trading activity which accounts for the number of trades and the volume of these trades is another important component of liquidity. According to Datar, Naik and Radcliff (1998), turnover ratio (TR) is defined as the ratio of the number of trades over the number of outstanding securities and is related to how quickly a dealer expects to turn around his position. Turnover ratio is thus the reciprocal of average holding period in that less liquid assets are allocated to investors with longer investment horizons. Consequently, investors would require a compensation for securities with lower turnover ratio resulting in high expected returns. However, the empirical findings of literature are conflicting, since the negative relationship between expected returns and turnover ratio, due to higher holding periods, could turn to positive when the adverse information effect is accounted for, i.e. higher level of turnover ratio indicates the adverse information which results in higher spreads and higher illiquidity. The next trading activity liquidity measure is the Dollar trading volume (DVOL) which is defined as the product of the total number of shares traded by the average price per share. This is assumed to be one of the most important determinants of the transaction cost which is decomposed to the inventory cost, the order processing cost and the adverse selection cost. Accordingly, the inventory cost or the holding cost of securities is a function of holding period which depends on trading volume allowing investors to reverse their position when dealing with heavily traded assets, resulting, thus, to a negative relationship between spread and dollar volume. In other words, dollar volume measures the speed of transaction to unwind the position and consequently, low dollar volume indicates illiquidity.

Another important component of liquidity is the price impact, which represents the changes of securities' prices due to changes of the dollar volume. High trading for a specific share with low impact on its price implies that the security is a liquid one. The Amihud ratio (Amihud 2002), a proxy for the price impact component of liquidity, is defined as the ratio of the absolute return over the dollar volume and expresses the average daily price change for $1 trading volume. Florakis, Gregoriou and Kostakis (2011) propose an alternative price impact metric controlling the size bias which is apparent at the Amihud ratio, by considering of the ratio of the absolute return to the turnover ratio.

While most of the empirical work on liquidity is the liquidity risk premium in an asset pricing framework and to the market-wide risk factor of liquidity, recently the risk of the liquidity risk premium is on the spot light. The former is about the positive relationship that is expected between asset returns and the illiquidity of asset returns, while the latter focuses on the investigation of the impact of the volatility of liquidity measures on asset returns. Chordia, Subrahmanyam and Anshuman (2001) are among the first who investigate the volatility of liquidity measures and they find a negative impact on asset returns on a cross-sectional level.

The motivation to investigate the second moment of liquidity is originated from some prior research. For instance, Chordia, Subrahmanyam and Anshuman (2001) suggest that the variability of liquidity could potentially indicate the heterogeneity of the clientele, who are holding the assets. The clientele hypothesis of Merton (1987) implies that the higher variability would represent a greater heterogeneity and thus lower expected returns. Another motivation behind the second moment of liquidity is that, investors might care the volatility of the liquidity distribution. The liquidity varies over time and higher variation in liquidity implies that a stock may be very illiquid or liquid at a time when there is a need of trading, by other words, an investor is exposed to a higher uncertainty of liquidity changing at the time he needs to trade, and the volatility of liquidity captures this risk. In addition, Pereira and Zhang (2010) claim that the states of liquidity are related to volatility of liquidity, thus, investor is able to adjust their trading timing regarding the change of liquidity and therefore may require lower expected returns when the asset is high volatile in liquidity. Based on these arguments and empirical findings, I examine the second moment[10] of liquidity on asset returns on the cross-sectional dimension.

The objective of this chapter is the informational content of the volatility of the liquidity measure, through the examination of several research hypotheses. The main work is a comparative analysis considering several dimensions of liquidity, such as transaction costs, trading activity and price impact, and two alternative metrics of volatility of liquidity.

[10] Aasymmetry in liquidity co-movemen, liquidity's skewness (third moment), has been documented by various researchers, e.g. Chordia, Sarkar and Subrahmanyam (2005), Kempf and Mayston (2005) and Hameed, Kang, and Viswanathan (2006). In this study, skewness is not included for simplicity. In fact, higher-order moments of liquidity are affecting asset return as well as optimal portfolio construction.

The first research hypothesis is concerned with whether the volatility of liquidity is priced in a conventional Fama-MacBeth framework. The coefficients of variation of liquidity is commonly as the proxy of liquidity volatility, in particular, the liquidity variability in month t is calculated as the standard deviation of the prior 36 monthly liquidity levels divided by the means of the prior 36 monthly liquidity. Comparatively, I use an additional proxy that is the standard deviation of daily liquidity levels in month t divided by the means of daily liquidity levels in month t. On the other hand, apart from the relevant literature which employs DVOL, TR, or R/DVOL as measurement of liquidity (Chordia, Subrahmanyam, and Anshuman (2001) and Pereira and Zhang (2010)), I investigate more liquidity measures involved as robustness check. Specifically, six individual liquidity measures are adopted to cover three dimensions of the concept of liquidity: DVOL and TR (trading activity), S and RS (transaction cost), and R/DVOL and R/TR (price impact).

Furthermore, I investigate potential commonalities of volatility of liquidity both within and across the examined liquidity components. Given the evidence of negative association between the volatility of liquidity and the cross-section equity return, one is attempted to explore the existence of the commonality of the volatility of liquidity. In order to obtain the systematic volatility of liquidity, I follow Korajczyka and Sadka (2008), who extract the systematic components of individual asset liquidity by the principal component analysis (PCA).

I also conduct an analysis based on which a mimicking factor on volatility of liquidity is constructed and examined in an asset pricing framework whether this volatility factor is priced. In addition to the commonality of the volatility of liquidity as the systematic component, I suggest an alternative variable to systematic volatility of liquidity as the proxy of a potentially priced risk factor relevant to the second moment of asset liquidity, that is, the volatility of market-wide liquidity. The construction of volatility of market liquidity is similar to the volatility of individual assets liquidity; that is, the former represents the second moment of market-wide aggregate liquidity. Being comparable to the volatility of individual asset liquidity, I employ two types of volatility of market-wide liquidity, of which one would represent the fluctuation of daily market-wide aggregate liquidity within month, and the other is essentially the coefficients of variation of monthly market-wide aggregate liquidity.

Finally, I aim to examine the factor pricing model on the market-wide volatility of liquidity. With the four systematic or market-wide variables of volatility of liquidity, I proceed to examine the risk premium of the relevant factor. It is, therefore, necessary to construct a mimicking portfolio to track the fluctuation of systematic or market-wide volatility of liquidity and its reflection on asset return. I follow Ang, Hodrick, Xing, and Zhang (2006) to obtain the mimicking portfolio pertinent to the systematic or market-wide volatility of liquidity. In the examination of the risk premium of risk factors under the Fama-French framework, I shall abide by the standard two-stage approach.

The rest of this chapter is organized as follows; Section 4.2 provides a brief literature review, Sections 4.3 and 4.4 explain the dataset and the research methodology, respectively, Section 4.5 presents the empirical findings and Section 4.6 concludes this chapter.

4.2 Literature Review

Many researchers have focused on the systematic component of liquidity on an aggregated market level. Chordia, Roll and Subrahmanyam (2001), Hasbrouck and Seppi (2001), and Huberman and Halka (2001) find commonality of order flow and liquidity across assets. Inspired by this observation, researchers examine whether the systematic liquidity risk is priced in asset return, e.g. the milestone work of Pástor and Stambaugh (2003). This empirical finding is of its own interest and also motivates Chordia, Subrahmanyam, Anshuman (2001) to investigate the second moment of market aggregated liquidity and its relationship with asset returns at a cross-sectional level.

Specifically, Chordia et.al (2001) is the first which introduces the investigation of the risk of liquidity risk and its explanatory power with respect to asset returns. They recruit liquidity measures which are relevant to trading activity (DVOL and TR) and find a solid negative cross-sectional relationship between the volatility of liquidity and asset returns on an asset pricing model framework. They define the volatility of liquidity as the standard deviation of the 36 lagged monthly observations of DVOL and TR divided by the mean of the prior 36 monthly observations. An alternative risk specification is also examined through the estimation of the conditional volatility of DVOL and TR using a GARCH (1,1) model as a robustness check.

Although a positive relationship is expected between the volatility of liquidity and the expected returns, the empirical findings suggest a negative one. They attribute this surprising relationship on the clientele hypothesis of Merton (1987) according to those securities that attract many investors and yield lower returns. Thus, variability of liquidity metrics could potentially indicate for the heterogeneity of the clientele holding the share and consequently, higher variability would imply a greater heterogeneity among the investors who hold the specific security, yielding lower returns.

In this direction, Pereira and Zhang (2010) investigate the negative impact of volatility of liquidity on asset returns. They adopt the price impact component of liquidity (R/DVOL) for a multiperiod investor who requires additional compensation for the adverse price impact of trading. Most importantly, they provide evidence that the puzzling negative effect is consistent with a risk-averter, fully rational and utility maximizing investor with a CRRA utility function.

By contrast, Akbas, Armstrong and Petkova (2011), in their manuscript, propose the use of a risk measure of liquidity which is based on daily liquidity observations over a month and find that the idiosyncratic component of risk of liquidity is priced positively on an asset pricing framework.

4.3 Data

The data are collected from CRSP and COMPUSTAT tape. The firms are common securities listed in NYSE-AMEX, providing closing price, bid price, ask price, trading volume, share of outstanding, and return at daily frequency, and book value, earning per share, dividend yield at the annual frequency. I transform the daily dataset in CRSP and annual dataset in COMPUSTAT into monthly data[1]. The bid/ask prices are only available after 1991 in CRSP data file. The dataset of other variables range from Jan., 1962 to Dec., 2011.[11] The risk free rate is computed using the one-month T-bill rate in US market. The Fama-French pricing factors are downloaded from French library website.

The following shares are removed from the dataset:

- shares that are traded at Nasdaq;
- shares that are not available in either CRSP or COMPUSTAT tape;
- shares that have fewer than two years prices or fewer than 15 trading days in one month;
- shares with extreme ask/bid prices (less than $5 or larger than $1000, or the closing bid prices are higher than ask prices);

[11] Note that in this chapter there is no business-cycle study as Chapter 3. It is not because it is meaningless to explore this issue of impact of liquidity volatility on asset returns in each different business-cycle, but it could potentially be complicated to conduct so many empirical tests in this chapter which mainly focus on the pricing of liquidity volatility.

- shares with negative BM values and those which are in the financial services sector;
- shares with extreme dollar market capitalisation, B/M, DY, and EP (less than 0.5% or lager than 99.5% percentile).

The data of the first and last trading month of each firm are also filtered. Overall, the number of firms in each month varies from 745 to 3154 with an average of 2050. The daily data from CRSP are transformed into monthly security characteristics by averaging or summing, in order to obtain monthly closing bid/ask prices and returns, trading volume, share of outstanding and market capitalization.

Moreover, I define three variables related to the short and long term momentum effects, RET_{23}, RET_{46}, RET_{712}, as the cumulative asset returns from the last three to last two months, from last six to four months, from last twelve to seven months, respectively. In addition, fundamental data are drawn from COMPUSTAT on an annual basis and then transformed into monthly. The dividend yield (DY) is obtained by the sum of all dividends paid over the previous months, divided by the share price at the end of the second to last month (Price-end). Similarly, I compute the book-to-market value (B/M) and the earnings-price ratio (EP). The monthly data statistics description corresponding to the pooled time-series averages of the cross-sections are presented in Penal A of Table 4.1.

RET is the monthly return for stocks, CAP stands for the market capitalization, P is the closing prices at the last trading day of each month, B/M is the monthly book-to-market ratio, EP is the earning-price ratio, DY is the dividend yield, RET_{23}, RET_{46}, RET_{712} are the cumulative monthly returns as defined above.

Specifically, I use six individual liquidity measures covering three dimensions of liquidity: the spread and relative spread (transaction cost), the dollar volume DVOL and turnover ratio TR (trading activity), and the return to dollar volume R/DVOL and the return to turnover ratio R/TR (price impact).

I construct the monthly liquidity measures based on the daily liquidity measures, removing the outliers (lower and upper 0.5 percentile) of each daily liquidity measure. In the following equations, i is the asset indicator, t or m is the day or month indicators, and n is the number of available trading days in each month.

The daily absolute spread is calculated as the difference between bid price and ask price. For a single stock, its monthly spread is calculated by averaging the daily spread over the month:

$$S_{i,m} = \frac{1}{n}\sum_{t=1}^{n}(ask_{i,t} - bid_{i.t}) \tag{4.1}$$

The daily relative spread is calculated as the ratio of the absolute spread over the price. For a single stock, its monthly spread is calculated by averaging the daily spread over the month:

$$RS_{i,m} = \frac{1}{n}\sum_{t=1}^{n}\frac{ask_{i,t} - bid_{i.t}}{price_{i,t}} \tag{4.2}$$

The dollar volume is the sum of the daily dollar volume, over month m:

$$DVOL_{i,m} = \sum_{t=1}^{n} DVOL_{i,t} \tag{4.3}$$

The turnover ratio at month m is calculated as the ratio of the number of shares traded in month m over the number of share outstanding:

$$TR_{i,m} = \frac{\sum_{t=1}^{n} trading\_volume_{i,t}}{share\_of\_outs\tan ding_{i,m}} \tag{4.4}$$

The return to dollar volume is the ratio of the average absolute return divided by the dollar volume, over month m:

$$R / DVOL_{i,m} = \frac{1}{n} \sum_{t=1}^{n} \left(\frac{|RET_{i,t}|}{DVOL_{i,t}} \right) \tag{4.5}$$

The return to turn over ratio over month m is the average daily ratio of absolute return over turnover ratio, over month m, where daily turnover ratio is obtained by the ratio of daily trading volume over the number of shares outstanding:

$$R / TR_{i,m} = \frac{1}{n} \sum_{t=1}^{n} \left(\frac{|RET_{i,t}|}{TR_{i,t}} \right) \tag{4.6}$$

The monthly liquidity measures descriptive statistics, obtained by the time-series averages of the cross-section data, is displayed in Table 4.1 Panel A.

The past performance indicator is based on the cumulative return of the past information as shown below:

$RET_{i,23}$: cumulative return of asset i from (t-3) to (t-2), the prior 3 to 2 months cumulative monthly return;

$$RET_{i,23,t} = \prod_{n=2}^{3} (1 + RET_{i,t-n}) - 1 \tag{4.7}$$

$RET_{i,46}$: cumulative return of asset i from (t-6) to (t-4), the prior 6 to 4 months cumulative monthly return;

$$RET_{i,46,t} = \prod_{n=4}^{6} (1 + RET_{i,t-n}) - 1 \tag{4.8}$$

$RET_{i,712}$: cumulative return of asset i from (t-7) to (t-12), the prior 12 to 7 months cumulative monthly return;

$$RET_{i,712,t} = \prod_{n=7}^{12} (1 + RET_{i,t-n}) - 1 \tag{4.9}$$

There exist significant correlations between the components of liquidity with an exception on the relationship between spread and trading activity. Within all liquidity components, positive and significant correlations are observed. The trading activity measures are negatively correlated with transaction cost components and positively with price impact constitutes. The turnover ratio is positively correlated with monthly cumulative returns, while the share price related measures, such as dollar volume, R/DVOL and relative spread, are correlated with market capitalisation. For the rest of the market-wide variables, prices of shares at the end of month are significantly correlated with market capitalizations, while the three indicators of firm value and firm performance (BM, EP and DY) and past performance are significantly correlated with each other.

The quantification of the risk of the liquidity measures is expressed through the standard deviation over the mean of the liquidity and is implemented through two approaches depending on the frequency of the data and the time period that they cover. The former is used by Akbas, Armstrong and Petkova (2011) and is based on daily observations of liquidity within each month, while the latter one was proposed by Chordia et.al (2001) using the 36 prior monthly liquidity values. The volatility of liquidity measures is expressed through the standard deviation over the expected mean of the liquidity:

$$vol_{i,t} = \frac{\sigma_{i,t}}{\mu_{i,t}} = \frac{\sqrt{\text{var}(liq_{i,t})}}{\frac{1}{T}\sum_{t-T}^{t-1} liq_{i,t}} \tag{4.10}$$

where $\sigma_{i,t}$ is the standard deviation of the prior T liquidity observations of asset i, and μ_t is the mean of the prior liquidity observations of asset i. Consequently, the paper uses two volatility specifications as follows:

$$vol1_{i,t} = \frac{\theta_{i,t}}{\upsilon_{i,t}} = \frac{\sqrt{\text{var}(liq_{i,\tau})}}{\frac{1}{T}\sum_{\tau=1}^{\tau=T} liq_{i,\tau}} \tag{4.11}$$

where $vol1_{i,t}$ denotes the realized volatility of liquidity in month t of asset i, which is computed by the daily liquidity $liq_{i,\tau}$ from day 1 to day T which is the number of trading days in month t of asset i, and $\theta_{i,t}$ is the standard deviation of daily liquidity levels of asset i in month t, and $\upsilon_{i,t}$ is the mean of the daily liquidity levels of asset i in month t:

$$vol2_{i,t} = \frac{\sigma_{i,t}}{\mu_{i,t}} = \frac{\sqrt{\mathrm{var}(liq_{i,t})}}{\frac{1}{36}\sum_{t-36}^{t-1} liq_{i,t}} \tag{4.12}$$

where $\sigma_{i,t}$ is the standard deviation of the prior 36 monthly liquidity levels of asset i, and μ_t is the mean of the prior month liquidity observations of asset i. The descriptive statistics of the volatility of liquidity is displayed in Panel B of Table 4.1.

Note, the high correlation between the mean and standard deviation of liquidity levels motivates us to construct the liquidity variability Vol1 (Vol2) in month t as the standard deviation of daily liquidity levels in month t (prior 36 monthly liquidity levels) divided by the mean of daily liquidity levels in month t (prior 36 monthly liquidity levels).

Besides, for each individual asset, it is expected that Vol1 would be larger and more volatile than Vol2. This is also obvious in the economical sense, considering that the Vol1 is constructed by the volatility of daily liquidity level within each month, while Vol2 is formed by the standard deviation of the prior 36 monthly liquidity over the corresponding moving average. Between the two categories of volatility of liquidity, the magnitude of Vol1 is larger than Vol2, but less volatile of Vol2.

Chodia et.al (2001) use the second volatility specification of liquidity Vol2 and investigate empirically its relationship with expected returns through a multifactor approach of a cross-sectional framework, concluding on a negative effect. Similarly, Pereira and Zhang (2010) find a negative relationship between the stocks excess return and second moment of liquidity level, even after controlling for other stock characteristics. Pereira and Zhang (2010) explain the negative relation as the less required compensation for investors who hold the asset with higher liquidity volatility, since the investors can take advantage of the liquidity state to adjust the trading strategy, in order to take the trading opportunity when the liquidity volatiles. By contrast, Akbas et.al (2011) extract the idiosyncratic component of risk of trading activity and through a cross-sectional analysis, and conclude in a positive association with expected returns.

4.4 Methodology

I divide the investigation into two parts based on the research objectives. The first part is in terms of the individual assets' volatility of liquidity, while the other part is concerning the volatility of market-wide aggregated liquidity.

4.4.1 Individual Asset Volatility of Liquidity

In this section, the volatility of liquidity is examined at individual asset level. Specifically, Fama-MacBeth regressions are conducted in order to examine the impact of liquidity volatility on asset returns, for six liquidity measures and two volatility liquidity specifications, respectively. In addition, common factors of liquidity volatility are extracted across assets from metrics by PCA method, and the factors are both with-measure and across-measure. Finally, these common factors are examined whether they are priced in asset returns using two stage regressions.

4.4.1.1 Cross-sectional Regression

The proposal to examine the relationship between the return and the volatility of liquidity is motivated by Chordia, Subrahmanyam, and Anshuman (2001) who measure the second moment of liquidity by the coefficient of variation using the prior 36 monthly data. Based on the Chordia, Subrahmanyam, and Anshuman (2001)'s method, Pereira and Zhang (2010) find similar results: there exists a negative relationship between the stock excess returns and second moment of liquidity level, even after controlling other firm characteristics. Pereira and Zhang (2010) explain the negative relation as the less required compensation for investors who hold the asset with higher volatility of liquidity, since they can take advantage of the liquidity state to adjust the trading strategy, in order to adopt the trading opportunity when the liquidity volatiles. However, Akbas, Armstrong and Petkova (2010) suggest an alternative proxy of volatility of liquidity which is computed using the within-month daily liquidity. Therefore, I attempt to study the volatility of individual asset liquidity by the two types of variable, Vol1 and Vol2.

Following extent literature, I employ the Fama-MacBeth approach in order to run cross-sectional regressions of individual monthly stocks return against its share characteristics including liquidity level and liquidity volatility.

The APT equation is expressed:

$$R_{i,m} - R_{f,m} = c_0 + \sum_{k=1}^{K} \beta_{i,k} f_{k,m} + \sum_{n=1}^{N} c_n Z_{n,i,m} + \varepsilon_{i,m} \tag{4.13}$$

where $R_{i,m}$ is monthly asset return, $R_{f,m}$ is risk free rate which is presented by US one-month T-bill rate, $\sum_{k=1}^{K} \beta_{i,k} f_{k,m}$ indicates the sum of premium of risk characteristics which are presented by the Fama-French factors $f_{k,m}$ and estimation of loadings $\beta_{i,m}$, and $Z_{n,i,m}$ is the value of non-risk characteristic n of firm i in month m. Here we are mainly concerned with the estimations of c_n, the main purpose of the investigation, which indicate the relationship between asset return and liquidity levels, as well as the liquidity volatilities, Vol1 and Vol2. Hence, the statistic model might be written as:

$$R^{*}_{i,m} = c_0 + \sum_{n=1}^{N} c_n Z_{n,i,m} + \omega_{i,m} \tag{4.14}$$

where $R^{*}_{i,m}$ is risk-adjusted return, $R_{i,m} - R_{f,m} - \sum_{k=1}^{K} \beta_{i,k} f_{k,m}$, where $\beta_{i,k}$ are estimated using a 60 months rolling window. Note the qualification of the rolling estimation for which I require there are at least 24 in 60 monthly data for each stock. The first rolling estimation starts from 30 monthly observations, and then extends to 31, 32..., until reaches 60.

For robustness check, I consider the dependent variables, asset return, with two specifications: excess return $R_{i,m} - R_{f,m}$ and risk-adjusted return $R^{*}_{i,m}$. I employ the Fama-MacBeth approach to run cross-sectional regressions of individual stocks excess return in month m against its share characteristics including liquidity level in month (m-2). The lag of firm characteristics follows convention of literature (e.g. Brennan, Chordia and Subrahmanyam (1998), Chordia, Subrahmanyam and Anshuman (2001), Pereira and Zhang (2010)) for the sake of avoidance of spurious relation between return and firm characteristics due to the effect of thin trading or bid-ask spread. Besides, all of the variables are taken logarithms to improve the efficiency of estimations.

The non-risk characteristics $Z_{n,i,m}$ are liquidity levels, volatility of liquidity and other control variables, in order to improve the efficiency of the estimate of the coefficients of liquidity. The controlling variables are firm size (CAP), Book-to-Market ratio (BM), Dividend Yield (DY), Earnings-Price ratio (EP), momentum cumulative returns (RET23, RET46, RET712), and reciprocal monthly prices (1/P). The use of CAP and BM are following Fama and French (1993) who discover that the firm size and Book-to-Market ratio are negatively and positively related to asset return, respectively. Firm characteristics DY and EP are also highly associated with shares return according to large literature. In spirit of Jegadeesh and Titman (1993), asset returns are highly related to the momentum effect, and the variables of cumulative past returns could demonstrate the effect to some extent. Besides, I am also mindful of Lee and Swaminathan's (1998) argument that the turnover may be a less than perfect proxy of liquidity because the relation between turnover and expected returns depends on how stocks performed in the past. Thus, I employ the prior cumulative monthly return, RET_{23}, RET_{46}, and RET_{712} in our cross-sectional regression tests. Finally, according on Miller and Scholes (1992), the low price assets are in financial distress, thus, the variable of reciprocal of share prices is controlled at the end of month.

The examination of the multifactor model is implemented through the t-statistic of the Fama-MecBeth (1973) approach:

$$\bar{c}_{i,j} = \frac{1}{M}\sum_{m=1}^{M}\hat{c}_{i,j,m} \tag{4.14}$$

$$se(c) = \sigma(c) / \sqrt{M} \tag{4.15}$$

$$t_c = \frac{\bar{c}}{se(c)} \tag{4.16}$$

where $\hat{c}_{i,j,m}$ is the estimated coefficient of the j^{th} characteristic of the i^{th} asset in month m, σ(c) is the sample standard deviation of the cross-sectional regressions estimates, and M is the number of observations.

The mean of time-series slopes of non-risk characteristics is reported: significant and positive coefficients indicate possible positive relationship between return and control variables, and vice versa.

4.4.1.2 Factor Decomposition

Through the Fama-MacBeth analysis I investigate whether the volatility of liquidity is priced. However, a question here is on whether there exists a common factor that drives the volatility of liquidity. The commonality across liquidity has been examined by Chordia, Roll and Subrahmanyam (2001), Hasbrouck and Seppi (2001). In order to answer this question, I investigate the systematic component of volatility of liquidity by applying the principal components analysis (PCA). Specifically, I follow the approach of Korajczyka and Sadka (2008), who extract the systematic components of individual asset liquidity by the PCA.

The analysis of the commonality characteristics is carried out at two levels, the within liquidity measure analysis and the across liquidity measures. The former is concerning the six separate individual liquidity measures, while the latter is regarding the aggregated liquidity. It is important to consider both within-measure and across-measure in this analysis. The within-measure common factors are extracted separately for different measures of liquidity using the PCA method, and each of the common factors is the component reflecting each liquidity dimension; while the across-measure is extracted across a large sample of assets and from a set of six correlated measures of liquidity volatility, and it is able to capture overlap or common component of all six measures of liquidity volatility. Examining the two sets of factors allows us to consider the pricing of both factors, for individual liquidity measure in each dimension, and for common component of all liquidity measurements.

The procedure of implementation is explained as follows.

In order to extract the commonality of the volatility of liquidity across all assets, I am based on the hypothesis that a set of common and idiosyncratic variables underline the volatility of liquidity. These variables represent, on the one hand, information about economic (systematic) fundamentals and, on the other hand, non-informational demands for liquidity/immediacy. In particular, I assume that the cross-sectional effect of Vol1 (or Vol2) for a set of n stocks can be represented statistically by the following linear factor model[12]:

$$vol^{j} = B^{j}F^{j} + \varepsilon^{j} \tag{4.17}$$

where vol^{j} is a n * T matrix of observations on the volatility of the liquidity measure j, n is number of assets in each month t, T is number of months, j = S, RS, DVOL, TR, R/DVOL or R/TR; where F^{j} is a k * T matrix of shocks to volatility of liquidity j that are common across the set of n assets (k is the dimension of the systematic components), B^{j} is a n * k vector of factor sensitivities to the common volatility liquidity shocks, and ε^{j} is an n * T matrix of asset-specific shocks to volatility of liquidity measure j. Systematic, or undiversifiable, shocks are those affecting most of the assets, while diversifiable shocks are those that have weak commonality across assets. The latent factors, F^{j}, are obtained by computing the eigenvectors corresponding to the k largest eigenvalues of the variance-covariance matrix:

$$\Omega^{j} = \frac{vol^{j}{}'*vol^{j}}{n} \tag{4.18}$$

while I denote the latent factors by Vol1_j or Vol2_j, where j indicates one of the specific six liquidity measures (S, RS, DVOL, TR, R/DVOL, R/TR). These common (latent) factors are denoted as "within-measure".

[12] It is assumed that Equation 4.17 is an approximate factor model. Actually Korajczyka and Sadka (2008) also adopt a similar model for factor decomposition.

In addition to estimating common factors for each measure of volatility of liquidity individually, by following Korajczyka and Sadka (2008) which extract the commonality across various liquidity measures, I also estimate common factors across all the six measures of liquidity (S, RS, DVOL, TR, R/DVOL, R/TR) from 1992 to 2011, and common factors across the four measures of liquidity (DVOL, TR, R/DVOL, R/TR) from 1962 to 2011. This is implemented similarly to the “within-measure” approach, but by stacking the volatility of liquidity into one matrix and then forming the variance-covariance matrix Ω and extracting the corresponding eigenvectors:

vol = [vol_1', vol_2', vol_3', vol_4', vol_5', vol_6']' from 1992 to 2011

or vol = [vol_3', vol_4', vol_5', vol_6']' from 1962 to 2011

(4.19)

I term the systematic factors extracted across the liquidity measures as "across-measure" factors:

$$vol = BF + \varepsilon \tag{4.20}$$

vol is a stacked $\sum n^j$ * T matrix, the elements are various liquidity volatility in different liquidity measures, (n is number of assets in each month t, T is number of months, j=one of the six liquidity measures; where B is a $\sum n^j$ * k vector of factor sensitivities to the common across-measure volatility of liquidity shocks, and ε is an $\sum n^j$ * T matrix of asset-specific shocks to across-measure volatility of liquidity measure. The latent factors, F , are obtained by computing the eigenvectors corresponding to the k largest eigenvalues of the Ω matrix:

$$\Omega = \frac{vol' * vol}{n} \tag{4.21}$$

The across-measure latent factors are denoted as $Vol1^4$ and $Vol2^4$, which are extracted from four liquidity measure matric, as well as $Vol1^6$ and $Vol2^6$, which are extracted from six liquidity measure matric. Overall, 12 within-measures and 4 across-measures comprise 16 specifications of the systematic variables of volatility of liquidity.

4.4.1.3 Factor Pricing

These commonalities of volatility of liquidity are investigated further, in order to examine whether the volatility of liquidity risk is priced on an asset-pricing framework, constructing a mimicking factor for the volatility of liquidity. For this purpose, I follow Ang, Hodrick, Xing, and Zhang (2006) through a three-stage analysis: the estimation of the base return, the construction of the mimicking factor, as well as the pricing by cross-sectional regressions.

The base return R is a matrix of decile portfolio returns on sensitivities to past volatility of liquidity. Specifically, for each security, I run a rolling window regression as shown below:

$$r_t^i - r_t^f = \alpha + \beta_{MKT}^i MKT_t + \beta_{SMB}^i SMB_t + \beta_{HML}^i HML_t + \beta_{Vol1\_j}^i Vol1\_j_t + \upsilon_t^i \qquad (4.22)$$

$$r_t^i - r_t^f = \alpha + \beta_{MKT}^i MKT_t + \beta_{SMB}^i SMB_t + \beta_{HML}^i HML_t + \beta_{Vol2\_j}^i Vol2\_j_t + \upsilon_t^i \qquad (4.23)$$

where i for individual asset iThe estimated coefficients $\beta_{Vol1\_j}^i$ and $\beta_{Vol2\_j}^i$, estimated by rolling window technique from the individual assets, indicate the sensitivity of asset returns to the volatility of liquidity common factor. By sorting securities on the basis of these sensitivities $\beta_{Vol1\_j}^i$ and $\beta_{Vol2\_j}^i$, I form 10 decile portfolios and consequently the base return:

$$R = [R_1 \ldots R_{10}] \tag{4.24}$$

These 10 monthly rebalanced portfolios are constructed based on the prior monthly volatility liquidity loading betas, comprising the following portfolio sensitivity:

$$\beta_p = \frac{\sum_{i_p}^{n_p} \beta^i_{Vol1\_j}}{n_p} \tag{4.25}$$

where n_p is the number of asset in portfolio p, thus the beta of portfolio p, β_p, is obtained from individual estimated β_i.

The base return R_t is then used to estimate the mimicking factor of the volatility of liquidity through the following regression:

$$Vol[1\,or\,2]\_j_t = a + b'R_t + \varepsilon_t \tag{4.26}$$

where $Vol1\_j_t$ and $Vol2\_j_t$ are the commonality of volatility of liquidity across all assets and liquidity measures, R_t is a vector of base assets returns, and b' is the vector of estimated coefficients which reflects the weight of each base return on the systemic volatility of liquidity. The mimicking factor is constructed so that it is able to track how the fluctuation of Vol1 or Vol2 is reflected on the asset return. According to Breeden et al. (1989) and Lamont (2001), the mimicking factor is provided by the product of the estimated coefficient and the base return and denoted as:

$$FVol[1\,or\,2]\_j_t = b'R_t \tag{4.27}$$

FVOL1_j or FVOL2_j reflects the mimicking factors of systematic risk of the liquidity volatility, (where j is one of the six individual liquidity measures - S, RS, DVOL, TR, R/DVOL and R/TR), and the results could be obtained from the individual liquidity measure or across-measures. Note that the mimicking factors obtained from non-tradable portfolios.

Once having the mimicking factor ready, one is able to exploit the two-stage regressions to estimate the significance of the volatility of liquidity risk factors, according to the Fama-MacBech's time-series and cross-sectional regressions:

$$R_{p,t} - r_t^f = \alpha + \beta_{MKT}^p MKT_t + \beta_{SMB}^p SMB_t + \beta_{HML}^p HML_t + \beta_{FVol[1or2]\_j}^p FVol[1\ or\ 2]\_j_t + \upsilon_t^p \qquad (4.28).$$

In the second stage, the betas of portfolios which are estimated from the first stage enter as the known estimation of variable in the cross-sectional regression:

$$E_t(R_{p,t} - r_t^f) = \lambda_0 + \lambda_{MKT}\beta_{MKT}^p + \lambda_{SMB}\beta_{SMB}^p + \lambda_{HML}\beta_{HML}^p + \lambda_{FVol(1or2)\_j}\beta^p{}_{FVol(1or2)\_j} + \varepsilon^p$$

(4.29),

where the coefficients $\lambda_{FVol(1or2)\_j}$ indicate the estimation of risk premia, and the estimation later on is reported in Panel B of Table 4.4.

4.4.2 Volatility of Market-wide Liquidity

The commonality of individual assets volatility of liquidity is extracted, by the Principal Component Analysis, to express the systematic volatility of liquidity across all assets. For the purpose of comparison, I introduce an alternative set of volatility of liquidity which contains the market-wide information, following the similar construction of $Vol1$ and $Vol2$.

4.4.2.1 Introduce Mvol1 and Mvol2

$$Mvol1_t = \frac{\theta_t^m}{\upsilon_t^m} = \frac{\sqrt{\text{var}(liq^m{}_\tau)}}{\frac{1}{T}\sum_{\tau=1}^{\tau=T} liq^m{}_\tau} \qquad (4.30),$$

where $Mvol1$ indicates the market-wide realized liquidity volatility, $liq^m{}_\tau$ is the market-wide aggregate liquidity in day τ in month t, and T is the number of trading days in each month.

$$Mvol2_t = \frac{\sigma_{i,t}}{\mu_{i,t}} = \frac{\sqrt{\text{var}(liq^m{}_t)}}{\frac{1}{36}\sum_{t-36}^{t-1} liq^m{}_t} \qquad (4.31),$$

where $Mvol2$ indicates the market-wide type 2 liquidity volatility, liq^m is the market aggregate liquidity in month t.

The construction of volatility of market liquidity $Mvol1$ and $Mvol2$, is similar to the volatility of individual assets liquidity $Vol1$ and $Vol2$. The type 1 volatility of liquidity represents the fluctuation of daily liquidity within month, while type 2 is essentially the coefficients of variation of monthly liquidity. Therefore, between the two types of volatility of market liquidity, $Mvol1$ is more volatile than $Mvol2$ by comparison.

4.4.2.2 Factor Pricing

Following the method of examining the equity risk premium, which is described above, I intend to form the mimicking factor by the post-ranking portfolio, and then examine the significance of risk factor in pricing model by the two-stage method. Since the approach is similar to the way on $Vol1\_j_t$ and $Vol2\_j_t$, here I briefly explain the procedures especially the different denotations, rather than repeating the equations from (4.22) to (4.29).

First, the sensitivities of assets to $Mvol1$ and $Mvol2$, termed as β^i_{Mvol1} and β^i_{Mvol2} are estimated in the pricing regression equations where the right-hand variables are Fama-French risk factors and volatility of market aggregate liquidity $Mvol1$ or $Mvol2$, using the rolling window technique.

Second, at each month t, all of the assets are ranked and sorted into 10 portfolios, on the basis of estimated β^i_{Mvol1} and β^i_{Mvol2} of month (t-1). Thus, the time-varying returns of 10 portfolios are going to be used in following stages.

Third, the 10 formed portfolios as the base assets, and the volatility of market aggregate liquidity is regressed on the base assets return. The vector of estimated coefficients is the weight vector, which determines the mimicking portfolios by tracking the reflection of $Mvol1$ and $Mvol2$ on asset returns. The mimicking factors are denoted as $FMvol1_t$ and $FMvol2_t$.

Finally, the standard two-stage method is applied to the examination the significance of mimicking factors. Using the information of the post-ranking portfolios and the time-varying coefficients of all risk factors (three factors in Fama-French framework and mimicking factor $FMvol1_t$ or $FMvol2_t$), $\hat{\beta}_t$ is obtained from time-series regressions. I then run the cross-sectional regressions to estimate the coefficients of $\hat{\beta}_t$, denoted by $\hat{\gamma}_t$.

4.5 Empirical Results

4.5.1 Individual Asset Volatility of Liquidity

4.5.1.1 Statistic Description of Vol1 &Vol2

The volatility of individual asset liquidity is calculated based on the equations (4.11) and (4.12), and Panel B of Table 4.1 reports the time-series average of the cross-sectional mean, median and standard deviation. Since Vol1 and Vol2 are obtained by the standard deviation over corresponding mean, and there would be one value of volatility of liquidity in each month of each asset, one can compare Vol1 and Vol2 when they are obtained from the same liquidity measure. According to the results in the statistic description table, it tells that the values of Vol1 are relatively higher than Vol2, generally speaking. Besides, for each asset and same liquidity measure, Vol2 process is smoother than the time-series process of Vol1. Moreover, another interesting phenomenon is observed, that is, the processes of volatility of asset liquidity (either Vol1 or Vol2) are highly correlated and nearly coincided between two liquidity measures which are in the same dimension, e.g. for an asset, Vol1 time-series process which is measured by Dollar Volume (DVOL) is highly coincided with Vol1 process which is calculated by the measure of Turnover Ratio (TR), where the two liquidity measures DVOL and TR both represent the liquidity dimension of trading activity.

4.5.1.2 Cross-sectional regression Results

The relationship between the asset return and individual volatility of liquidity is examined based on regression of equation (4.14). By applying the Fama-MacBech method in the regressions estimation, for each month, all of the individual assets information variables, firm size (CAP), Book-to-Market ratio (BM), Dividend Yield (DY), Earnings-Price ratio (EP), momentum cumulative returns (RET23, RET46, RET712), and reciprocal monthly prices (1/P), are used for the cross-sectional regressions. The Panel A (Panel B) of Table 4.2 presents the estimated coefficients of the Vol1 (Vol2) and equity characteristics. For the purpose of robustness check, there are two sets of dependent variables for examinations: asset excess return and Fama-French risk adjusted return. Furthermore, I add the individual asset liquidity level as additional independent variable. Thus, for each one of the six liquidity measures, there would be four sets of results, resulting from two specifications of liquidity volatility and two sets of depended variables. Note that the coefficients are estimated by monthly cross-sectional regressions and the results presented in Table 4.2 are time-series average of monthly cross-sectional regression estimations.

Our main interest is of the estimated coefficients of Vol1 and Vol2. On one hand, from Penal A, the estimated slopes of Vol1 are negative and significant in the measures of spread (S) and relative spread (RS), with or without the liquidity levels (S or RS) jointed. In particular, the coefficients of spread (S) are both -0.003 in either the excess return or risk-adjusted group, while those of relative spread (RS) is -0.002 when the depended variable is excess return or -0.001 when regressed on risk-adjusted returns. While for results from other liquidity measures, the coefficients of Vol1 are insignificant, though the coefficients of liquidity levels are consistently significant as shown in Chapter 3. On the other hand, from Penal B, the estimated coefficients of Vol2 of four liquidity measures, Dollar Volume (DVOL), Turnover Ratio (TR), Return to Dollar Volume (R/DVOL) and Return to Turnover Ratio (R/TR), are negative and significant; the time-series average of cross-sectional regression estimations are around -0.001 or -0.002 by the four liquidity measures. However, the results in columns of spread (S) and relative spread (RS) are insignificant. Besides, it is found that the estimation slopes of liquidity levels (DVOL, TR, R/DVOL and R/TR) are also significant. In generally, the coefficients estimation of the

Vol2 variables is consistent, with or without the liquidity level variables included in regressions, when the dependent variables are excess returns. Nevertheless, the effect of liquidity levels dominates the liquidity volatility Vol2 when risk-adjusted returns as the dependent variables in regressions.

To conclude, it is discovered that, between the two specifications of volatility of liquidity, Vol1 and Vol2, the former is significantly and negatively related to asset return when liquidity is measured in the dimension of transaction cost (S or RS), while the latter, Vol2, is statistically significant and negatively related with asset return in the liquidity dimensions of trading activity (DVOL or TR) and price impact (R/DVOL or R/TR). In the research of Chordia, Subrahmanyam, and Anshuman (2001) and Pereira and Zhang (2010), they only investigate the volatility of liquidity by Vol2, and the liquidity measures are restricted by trading activity (DVOL or TR) and price impact (R/DVOL). The results in this thesis are not only in line with literature, but also provide the significant results in an alternative type of volatility of liquidity (Vol1) and additional liquidity measures (S, RS and R/TR).

An additional finding is that, the relationship between asset returns and volatility of liquidity (Vol1 or Vol2) is consistently negative, across six liquidity measures examined. In other words, the negative association between the volatility of liquidity and asset returns has nothing to do with the liquidity measurement, unlike the relationship between asset return and liquidity level, the sign itself depends on the usage of proxies of liquidity.

4.5.1.3 Commonality Components Extraction

In order to examine whether there exists commonality across all assets in terms of volatility of liquidity, I employ the Principal Component Analysis (PCA) on Vol1 and Vol2. The percentages of cross-sectional variance explained by the first three components are displayed in Panel A of Table 4.3. Among all of the liquidity measures, the first three components of Vol1 and Vol2 explained the most variance when the liquidity is measured by S and RS, reaching more than 70% in Vol1 and 80% in Vol2. For the other liquidity measures, the first three components of Vol1 and Vol2 account lower explanation power, ranging from roughly 50% to 60%. In addition to the components from the volatility of liquidity which is measured individually, this chapter also investigates the "across-measure" components of volatility of liquidity. There are two "across-measures" in the results - one is from four groups of volatility of liquidity obtained by four liquidity measures (DVOL, TR, R/DVOL and R/TR) and the sample data is from 1961 to 2011, and the other is from all the six measures (S, RS, DVOL, TR, R/DVOL and R/TR) using the data from 1991 to 2011 due to the data availability of RS and S. From 65% to 70% percentage of variance is explained by the first three components of Vol1 and Vol2 in the two "across-measures".

Since the results from PCA have convinced that the commonality of volatility of liquidity exists, I propose to extract the systematic component across assets. The approach of extracting is based on equations (4.20) and (4.21). The statistic description of the systematic factor of Vol1 and Vol2 are reported in Table 4.3 Penal B. It denotes the common factors as Vol1_j and Vol2_j, where j is the specific one of the six liquidity measures (S, RS, DVOL, TR, R/DVOL and R/TR); for the "across-measure" I denote $Vol1^4$, $Vol2^4$ and $Vol1^6$, $Vol2^6$. All of those variables represent the systematic volatility of liquidity.

4.5.1.4 Post-ranking Portfolio

Based on the results from the relationship between asset return and individual asset volatility of liquidity, it is found that the second moment of individual asset liquidity is negatively associated with asset return. However, the categories of volatility of liquidity depends on the measure (or the dimension) of liquidity. Specifically, Vol1 is significantly related with asset return in the liquidity dimension of transaction cost, i.e., measured by S and RS; Vol2 is significant when the liquidity is measured in the dimensions of trading activity (DVOL and TR) and price impact (R/DVOL and R/TR). Therefore, I consider these results to explore the pricing of risk premium of asset liquidity volatility. In particular, I intend to examine the systematic volatility of liquidity, and the potential task is concentrated on those presented significant results above, i.e. Vol1_S, Vol1_RS, and Vol2_DVOL, Vol2_TR, Vol2_R/DVOL, Vol2_R/TR, as well as the “across-measure” systematic factors $Vol2^6$ and $Vol2^4$. Note I investigate the “across-measure” regarding $Vol2^6$ and $Vol2^4$ instead of on $Vol1^6$ or $Vol1^4$, because the insignificant relationship between asset return and the volatility of liquidity in two dimensions of trading activity and price impact.

The sensitivities of assets returns to the systematic volatility of liquidity are estimated in the rolling window regressions, under the framework of Fama-French pricing model. The firms are ranked and sorted into 10 portfolios on the basis of last month’s $\beta^i_{Vol1\_j}$ and $\beta^i_{Vol2\_j}$, as well as $\beta^i_{Vol2\_4}$ and $\beta^i_{Vol2\_6}$. Penal A of Table 4.4 demonstrates various summary statistics for quintile portfolios sorted by past $\beta^i_{Vol1\_j}$ and $\beta^i_{Vol2\_j}$ over the previous month using equations (4.22) and (4.23). The time-series average results of the 10 post-ranking portfolios, including $\beta^i_{Vol1\_j}$ and $\beta^i_{Vol2\_j}$, value-weighted portfolio return, Fama-French alpha, and firms’ average market capitalisation are displayed in Panel A of Table 4.4. The portfolio 1 has lowest sensitivity to systematic volatility of liquidity, while portfolio 10 is most sensitive to the change of systematic liquidity volatility. By construction, since the portfolios are constructed by ranking on past $\beta^{i}_{Vol1\_j}$ and $\beta^{i}_{Vol2\_j}$, the loadings monotonically increase from small (portfolio 1) to large (portfolio 10). Each liquidity measure provides us different results. The loading coefficients of systematic volatility of liquidity range from (-6.366, 4.190), (0.045, 4.335), (0.002, 3.740), (-7.093, 4.111), (-5.190, 2.787), (-4.086, 4.253), when the liquidity measured by DVOL, S, RS, TR, R/DVOL, R/TR, respectively. When the systematic liquidity volatility is extracted from 6 or 4 liquidity volatility matrices, the beta ranges from (-1.418, 0.888) or (-6.503, 5.240), respectively. In addition, being consistent with the negative price of individual asset volatility of liquidity risk found from the results in Table 4.2 that reports the negative relationship between asset return and the volatility of asset liquidity, one can see lower average excess returns and FF-3 alphas with higher past loadings of $\beta^{i}_{Vol1\_j}$ and $\beta^{i}_{Vol2\_j}$. All the differences between quintile portfolios 1 and 10 are significant at the 5% level, and a joint test for the alphas equal to zero rejects at the 5% level for the FF-3 model. In particular, the 1-10 spread in average returns between the quintile portfolios with the highest and lowest $\beta^{i}_{Vol1\_j}$ and $\beta^{i}_{Vol2\_j}$ coefficients is 0.0021, 0.0044, 0.0053, 0.0023, 0.0024, 0.0022 per month, when the liquidity is measured by DVOL, S, RS, TR, R/DVOL, R/TR, respectively, and 0.0047 or 0.0020 when the systematic liquidity volatility is exacted from 6 or 4 liquidity volatility matrices, respectively. After controlling the FF-3 factor, the 1-10 spreads are exacerbated to 0.4612, 0.1291, 0.1172, 0.4911, 0.3162, or 0.3525 per month, by the liquidity measures of DVOL, S, RS, TR, R/DVOL, and R/TR, respectively; besides, FF-3 alphas change to 0.1590 or 0.5198 per month, with respect to across-6-measure or across-4-measure, respectively.

4.5.1.5 Ex post Factor

Although the differences in average returns and alphas corresponding to different $\beta^{i}_{Vol1\_j}$ and $\beta^{i}_{Vol2\_j}$ loadings are very significant and impressive, one could not yet claim that these differences are due to systematic volatility of liquidity risk, but need further investigation and evidence on pricing. In particular, in order to measure ex post exposure to the volatility of liquidity risk and examine the risk premium of systematic liquidity volatility, one might need to construct a mimicking portfolio which is able to track the reflection of systematic liquidity volatility on asset return. By following Breeden, Gibbons, and Litzenberger (1989), an ex post factor that mimics aggregate volatility risk is constructed. I hereby term this mimicking factor FVOL. The tracking portfolio is the portfolio of asset returns which are maximally correlated with the systematic volatility of liquidity using a set of basis assets. This allows us to examine the contemporaneous relationship between factor loadings and average returns. In specific, the basis assets are a group of assets which have various sensitivities to past systematic volatility of liquidity $Vol1\_j_t$ or $Vol2\_j_t$. By equations (4.26), the weights of each asset on the mimicking portfolios are estimated in the regressions. The multiplication of weight vector and base asset return vector, $b'R_t$, are denoted the $FVol1\_j_t$ and $FVol2\_j_t$. The time-series average of the tracking portfolios return are displayed in Panel B of Table 4.4. The results show that the returns of the mimicking portfolios are positive on average. The mimicking portfolio varies when the liquidity is measured by different proxies, and the mean portfolio return over all measures is 0.0058 on monthly basis (6.96% per annum). The correlation between $FVol1\_j_t$ (or $FVol2\_j_t$) and the FF_3 factors are in Table 4.5.

4.5.1.6 Pricing of Ex post Factors

Given the evidence for the abnormal performance of portfolios constructed on the basis of the asset returns' sensitivities to the past systematic volatility of liquidity, $Vol1\_j_t$ or $Vol2\_j_t$, I am motivated to examine whether the mimicking aggregate volatility of liquidity factor, $FVol1\_j_t$ (or $FVol2\_j_t$), is priced in the portfolios' return, and helps to explain the cross-sectional variation in these portfolios' returns. The method used is a two-stage approach. In the first stage, the time-series estimations of beta of pricing factors are obtained by Equation (4.28) by rolling-window technique. In specific, the dependent variables are post-ranking portfolio excess return, the independent variables are FF-3 factors as well as mimicking volatility of liquidity factors $FVol1\_j_t$ (or $FVol2\_j_t$). Thus, each portfolio has a set of time-series betas coefficients corresponding to four risk factors. The second stage involves the estimation of monthly cross-sectional regressions, based on Equation (4.29), of the 10 excess portfolios' returns on the corresponding betas that were obtained from the first-stage process. Lambdas γ_t' represent the risk premium coefficients associated with each beta. The main hypothesis test here is whether the time-series average of the estimated coefficients $FVol1\_j_t$ (or $FVol2\_j_t$) is positive and statistically significant, which is perceived as evidence that the mimicking factor is priced. The lambda coefficients and their Fama-MacBeth t-statistics are displayed underneath the results of lambda, in columns 3-7 of Panel B of Table 4.4. Note that, I am interested in the pricing factor related to Vol1 when the liquidity is measured by transaction cost, and the factor related to Vol2 when liquidity is measured by trading activity as well as pricing impact, according to the evidence that negative relationship between asset return and the volatility of liquidity which is measured by different liquidity aspects (the results are in Table 4.2). Therefore, for the lambda estimations of $\gamma'_{FVol1\_j,t}$(or $\gamma'_{FVol2\_j,t}$), I restrict our examination on Vol1_S, Vol1_RS, and Vol2_DVOL, Vol2_TR, Vol2_R/DVOL, Vol2_R/TR, as well as the "across-measure" systematic factor $Vol2^6$ and $Vol2^4$. The corresponding lambda estimations of these systematic volatility of liquidity are $\gamma'_{FVol1\_S,t}$, $\gamma'_{FVol1\_RS,t}$, $\gamma'_{FVol2\_DVOL,t}$, $\gamma'_{FVol2\_TR,t}$, $\gamma'_{FVol2\_R/DVOL,t}$, $\gamma'_{FVol2\_R/TR,t}$, $\gamma'_{FVol2\_6,t}$, $\gamma'_{FVol2\_4,t}$. Table 4.4 presents the estimated lambda coefficients for the 10 value-weighted portfolios sorted according to the asset returns' sensitivities to the past systematic volatility of liquidity, $Vol1\_j_t$ or $Vol2\_j_t$. For the purpose of comparability, I report results for Fama-French model which has been augmented by the $FVol1\_j_t$ (or $FVol2\_j_t$) factor, when the liquidity is measured by 6 different measures. Across all liquidity measures, the estimation of lambda $\gamma'_{FVol1\_j,t}$ (or $\gamma'_{FVol2\_j,t}$) are significant and positive. Besides, one can also compare the time-series average of mimicking portfolio return with the estimation $\gamma'_{FVol1\_j,t}$ (or $\gamma'_{FVol2\_j,t}$), by the ratios of the estimation of the risk premium of systematic volatility of liquidity over the mimicking portfolio returns, which indicates the estimation precisions. The ratios are in the last column of Panel B, Table 4.4. The estimated coefficients of lambda, averagely, account for 68% of mimicking factor portfolio, across all of the liquidity measures. In particular, when the liquidity is measured by R/TR, the estimation of $\gamma'_{FVol2\_j,t}$ is 0.0035 while the mean return of mimicking portfolio is 0.0037.

4.5.2 Mvol1 and Mvol2

4.5.2.1 Statistic Description

Table 4.6 reports the statistic information of Mvol1 and Mvol2 of each individual liquidity measures. The figures 4.2 and 4.3 illustrate the time-series process. In general, the values of Mvol2 are larger than that of Mvol1 at the same time point, across all of the liquidity measures; however, the values of Mvol2 are relatively less volatile than Mvol1. Besides, the figures of Mvol1 (or Mvol2) of the same dimension of liquidity measures are highly correlated with each other, even nearly overlap in the time-series, e.g. Mvol1 of DVOL and Mvol1 of TR, where DVOL and TR both measure the dimension of trading activity of liquidity. This phenomenon is consistent with the pattern investigated in systematic volatility of liquidity Vol1 and Vol2. Figures 4.2 and Figure 4.3 illustrate the time-series of Mvol1 and Mvol2, respectively, of six liquidity measures.

4.5.2.2 Ex post Factor Pricing Results

Following the methodology and procedures on Vol1 and Vol2 of Section 4.4.1.4, I form the tracking portfolios which are able to reflect the fluctuation of volatility of market-wide liquidity and capture the impact of the fluctuation on the assets returns. Based on Mvol1 and Mvol2, which are the volatility of market-wide liquidity, I construct the mimicking portfolios and denote them as $FMVOL1\_j$ and $FMVOL2\_j$, where j is the specific one of liquidity measures, S, RS, DVOL, TR, R/DVOL, and R/TR. The time-series mean returns of these mimicking portfolios are displayed in the last column of Panel A and Panel B of Table 4.7. The average portfolios return of $FMVOL1\_j$ is 0.0079 per month (with annualised return 9.48%), while $FMVOL2\_j$ is 0.0182 per month (with annualised return 21.84%).

Given the mimicking portfolios of Mvol1 and Mvol2, namely, $FMVOL1\_j$ and $FMVOL2\_j$, one is able to estimate the risk premia of risk factor of market liquidity volatility. Conventionally, one could adopt the two-stage method, where the first stage involves estimating the coefficients of factor loadings, and then using these estimations of loadings in the second stage of cross-sectional regressions. The estimations of risk premia, lambdas γ_t', are reported in Table 4.6.

Since $FMVOL1\_j$ or $FMVOL2\_j$ are introduced into Fama-French three-factor pricing model, the estimations of $\gamma'_{FMVOL1\_j,t}$ and $\gamma'_{FMVOL2\_j,t}$ in each specific liquidity measure would be interesting. Unlike the results from Table 4.4 which is regarding $\gamma'_{FVol1\_j,t}$ (or $\gamma'_{FVol2\_j,t}$), it is found that the pricing of the market-wide liquidity volatility factors in the assets return essentially varies across liquidity proxies. In particular, the coefficients of $FMVOL1\_j$ are positive and significant if the liquidity is proxied by DVOL, RS, R/DVOL or R/TR, while coefficients of $FMVOL2\_j$ is significantly positive only when the liquidity is measured by DVOL, S and RS. In other words, $FMVOL1\_j$ is significantly priced in asset returns when liquidity is proxied by DVOL, RS, R/DVOL or R/TR, $FMVOL2\_j$ is priced when liquidity is measured by DVOL, S and RS. However, for other liquidity measurement, those mimicking factors of market-wide liquidity volatility are not priced in asset returns.

Besides, the magnitude of the estimation of risk premium, the significant lambdas $\gamma'_{FMVOL1\_DVOL,t}$, $\gamma'_{FMVOL1\_RS,t}$, $\gamma'_{FMVOL1\_R/DVOL,t}$, $\gamma'_{FMVOL1\_R/TR,t}$, are very close to the mean returns of the mimicking factor portfolios, since the ratio of lambda values over mimicking portfolio mean return are higher than 80%. Nevertheless, the results from $\gamma'_{FMVOL2\_DVOL,t}$, $\gamma'_{FMVOL2\_S,t}$, $\gamma'_{FMVOL2\_RS,t}$ are not satisfactory due to relatively low ratios.

4.6 Conclusion

I investigate the equity volatility of liquidity and its impact on asset return, where the liquidity measurement covers three dimensions (trading activity, transaction cost and price impact). In addition to the volatility of liquidity, Vol1, which is able to capture the variation of daily liquidity within each month, used in literature, I employ another proxy, Vol2, which reflects the fluctuation of liquidity of prior months. It is detected that Vol1 holds the significant and negative relationship with asset return in the dimension of transaction cost of liquidity, while Vol2 is negatively associated with asset return when the liquidity is measured in the aspect of trading activity and price impact. Furthermore, I construct a mimicking portfolio to track the systematic risk of volatility of liquidity, with respect to Vol1 and Vol2. In particular, the systematic volatility of liquidity is extracted from the cross-sectional individual asset volatility of liquidity, by the approach of PCA. The idea of mimicking factor construction is from Ang, Hodrick, Xing, and Zhang (2006). This chapter provides the evidence that the systematic risk of volatility of liquidity is priced in the asset returns.

Besides, I use an alternation of volatility of market-wide liquidity in order to examine the pricing of systematic risk of volatility of liquidity. The volatility of market-wide liquidity is obtained by the similar construction of Vol1 and Vol2, but concerning aggregate market-wide liquidity instead of individual asset liquidity, and I term them as Mvol1 and Mvol2. It is found that the mimicking factors, which are relevant to Mvol1 and Mvol2, are priced in asset return, only in specific dimensions of liquidity.

Table 4.1: Descriptive Statistics of firm fundamentals, liquidity measures and volatility of liquidity

This table demonstrates the statistics of monthly variables, which are going to be used in the Fama-MacBech cross-sectional regressions. The mean, median, standard deviations are obtained by the time-series average of monthly cross-sectional mean, median, standard deviation. The listed variables are observed or calculated from a sample of average 2050 NYSE-AMEX firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. The fundamental control variables and six liquidity measures variables are reported in Panel A. RET is the monthly return of assets. CAP is the market capitalizations of firms. PRICE denotes the closing prices at the end of month. B/M is the book-to-market ratio, obtained by the ratio of last year's book value to the market prices at the end of each month. EP is the earning price ratio. DY is the dividend yield, which is calculated by the sum of last year's dividend over the prices at the end of each month. Ret 23, Ret46, Ret712 are cumulative returns of over the second through third, fourth through sixth, and seventh through twelfth months prior to the present months, respectively. DVOL denotes sum of daily dollar trading volumes within month for each stock. S is the value of absolute monthly spreads, which are obtained by taking average of the daily absolute spread within each month. RS represents relative spread, namely, the ratio of absolute spread to share closing prices, and the monthly relative spread is the average of daily relative spread. Note that the data availability of S and RS is from January, 1991 to December, 2011. TR is the monthly turnover ratio, calculated by monthly trading volume over number of shares outstanding in each month. R/DVOL denotes the ratio of absolute return to dollar volume, while the monthly R/DVOL is the average daily R/DVOL. R/TR is defined similar to the previous variable, but the absolute return is divided by daily turnover ratio. In Panel B, the results are two types of volatility of liquidity, where liquidity is measured by six different measures. Vol1 indicates liquidity variability in month t as the standard deviation of daily liquidity levels in month t divided by the mean of daily liquidity levels in month t, while Vol2 in month t is obtained by the standard deviation of prior 36 monthly liquidity levels divided by the mean of prior 36 monthly liquidity levels. For each asset, Vol1 and Vol2 are calculated every month, respectively.

Panel A	**Mean**	**Median**	**Standard deviation**
CAP	1.4247	0.3331	3.5107
BM	0.7711	0.6039	0.7790
EPS	0.0801	0.0676	0.1470
DY	0.0344	0.0246	0.0494
RET23	0.0245	0.0181	0.1297
RET46	0.0365	0.0293	0.1555
RET712	0.0745	0.0639	0.2144
PRICE	27.05	21.50	23.45
S	0.2284	0.1978	0.1410
RS	0.0122	0.0101	0.0078
DVOL	130.05	25.95	251.79
TR	68.23	45.62	99.61
R/DVOL	0.2421	0.1126	0.3296
R/TR	0.0185	0.0136	0.0165

Panel B		**Mean**	**Median**	**Standard deviation**
S	Vol1	0.4999	0.4543	0.2422
RS		0.5046	0.4563	0.2467
DVOL		0.7932	0.6997	0.3943
TR		0.7848	0.6976	0.3772
R/DVOL		1.0312	0.9657	0.3294
R/TR		1.0262	0.9632	0.3216
S	Vol2	0.4155	0.3858	0.1766
RS		0.4689	0.4412	0.1867
DVOL		0.6212	0.5550	0.3006
TR		0.5485	0.4945	0.2519
R/DVOL		0.5904	0.5449	0.2256
R/TR		0.4670	0.4425	0.1458

Table 4.2: Cross Sectional analysis of asset returns on firm fundamentals and volatility of liquidity

This table reports the cross-sectional regressions results. The data use in the cross-section regressions are from a sample of average 2050 NYSE-AMEX common listed firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. The dependent variables in the row are monthly individual asset excess return and Fama-French risk adjusted return. There are two sets of independent variables: one set is Vol1 (2), CAP, BM, EP, DY, RET23, RET46, RET712 and 1/P and liquidity measures (DVOL, S, RS, RE, R/DVOL, R/TR respectively), where the liquidity variability Vol1 (Vol2) in month t as the standard deviation of daily liquidity levels in month t (prior 36 monthly liquidity levels) divided by the mean of daily liquidity levels in month t (prior 36 monthly liquidity levels), by equation (1) and (2); CAP is the market capitalizations of firms; BM is the book-to-market ratio, obtained by the ratio of last year's book value to the market prices at the end of each month; EP is the earning-price ratio, calculated by the earnings over the prior year divided by the share prices at the end of each month; DY is the dividend yield, which is calculated by the sum of last year's dividend over the prices at the end of each month; Ret 23, Ret46, Ret712 are cumulative returns of over the second through third, fourth through sixth, and seventh through twelfth months prior to the present months, respectively; 1/P denotes the reciprocal of closing prices at the end of month; liquidity measures (DVOL, S, RS, RE, R/DVOL, R/TR respectively): S is the value of absolute monthly spreads, which are obtained by taking average of the daily absolute spread within each month; RS represents relative spread, namely, the ratio of absolute spread to share closing prices, and the monthly relative spread is the average of daily relative spread; DVOL denotes sum of daily dollar trading volumes within month for each stock; TR is the monthly turnover ratio, calculated by monthly trading volume over number of shares outstanding in each month; R/DVOL denotes the ratio of absolute return to dollar volume, while the monthly R/DVOL is the average daily R/DVOL, R/TR is defined similar to the previous variable, but the absolute return is divided by daily turnover ratio. Panel A reports the results related to Vol1, while Panel B is in terms of Vol2. Each one specific liquidity measure provides a group of results and the cross-sectional regressions generate monthly coefficients for each independent variable. The coefficients reported in the table are obtained by the

	S				RS				DVOL			
	Excess Return		Risk-adjust Return		Excess Return		Risk-adjust Return		Excess Return		Risk-adjust Return	
vol1	-0.003*	-0.003*	-0.003*	-0.004*	-0.002*	-0.002*	-0.001*	0.000*	0.000	0.000	0.000	0.000
	-8.384	-8.672	-2.118	-2.295	-4.686	-4.531	-2.641	-1.897	0.592	1.118	0.444	1.168
cap	-0.001*	0.000	0.000*	-0.001	-0.001*	-0.001*	0.000*	-0.001*	-0.001*	0.000	0.000*	0.001
	-5.042	-1.025	-1.997	-1.317	-4.612	-3.126	-1.959	-2.198	-1.792	0.857	-1.831	0.466
bm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001*	0.001*	0.006*	0.008*
	0.493	0.699	0.552	0.438	0.198	0.177	0.592	0.544	3.004	3.150	2.632	2.891
eps	0.002*	0.002*	0.003*	0.001*	0.003*	0.003*	0.001*	0.010*	0.005	0.004	0.009*	0.005
	2.587	2.390	2.646	2.199	3.149	3.233	2.431	2.688	1.397	1.483	1.803	1.575
dy	0.007	0.005	0.004*	0.005	0.001	0.001	0.001	0.001	-0.020	-0.026*	-0.041	-0.096*
	1.259	0.960	1.920	0.677	0.213	0.228	0.754	0.862	-1.501	-2.411	-1.311	-2.254
ret23	0.001	0.002	0.000	0.010	0.001	0.001	0.000	0.001	0.005*	0.006*	0.010*	0.005*
	0.350	0.419	0.746	0.591	0.189	0.220	0.918	0.289	1.889	2.446	1.931	2.177
ret46	-0.001	-0.001	0.000	0.000	0.005*	0.005*	0.002*	0.007*	0.010*	0.010*	0.005*	0.005*
	-0.264	-0.299	-0.776	-0.893	1.976	1.947	1.902	1.975	4.360	4.891	1.903	1.912
ret712	-0.006*	-0.006*	-0.006*	-0.006*	-0.002	-0.002	-0.003	-0.003	0.007*	0.007*	0.006*	0.005*
	-3.282	-3.333	-1.823	-2.523	-1.213	-1.216	-1.544	-1.578	4.604	5.019	2.384	5.497
1/p	0.003*	0.004*	0.006*	0.009*	0.003*	0.003*	0.003*	0.001*	0.002*	0.002*	0.005*	0.010*
	3.733	5.204	1.925	1.861	5.193	5.075	2.533	2.614	3.585	3.418	1.852	1.948
measure		0.002*		0.002*		0.000		0.000		-0.001*		-0.008*
		3.570		1.941		0.659		0.142		-2.366		-1.824

Table 4.2: Cross Sectional analysis of asset returns on firm fundamentals and volatility of liquidity

Panel A (continued)	TR				RTODVOL				RTOTR			
	Excess Return		Risk-adjust Return		Excess Return		Risk-adjust Return		Excess Return		Risk-adjust Return	
vol1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
	_0.496_	_0.858_	_0.263_	_0.124_	_0.270_	_-0.269_	_0.749_	_-0.138_	_0.713_	_0.293_	_0.482_	_0.572_
cap	-0.001 *	-0.001 *	0.000 *	-0.001 *	-0.001 *	0.000	0.000 *	0.001	0.000 *	0.000 *	-0.001 *	0.000 *
	_-2.017_	_-2.422_	_-2.205_	_-2.811_	_-1.916_	_0.514_	_-2.044_	_0.350_	_-1.712_	_-1.705_	_-1.967_	_-1.921_
bm	0.001 *	0.001 *	0.001 *	0.000	0.001 *	0.001 *	0.001 *	0.001 *	0.001 *	0.001 *	0.000 *	0.001 *
	_2.422_	_2.614_	_1.896_	_1.667_	_2.440_	_2.512_	_2.293_	_2.162_	_2.622_	_2.706_	_2.555_	_1.943_
eps	0.005 *	0.005 *	0.003 *	0.001	0.004	0.004	0.003	0.004	0.005	0.005	0.002 *	0.003
	_1.636_	_1.724_	_1.815_	_1.499_	_1.467_	_1.443_	_1.393_	_1.518_	_1.567_	_1.555_	_1.891_	_1.608_
dy	-0.018	-0.024 *	-0.003 *	-0.008 *	-0.018	-0.021 *	-0.095	-0.015	-0.020 *	-0.023 *	-0.004 *	-0.039 *
	_-1.451_	_-2.347_	_-1.975_	_-2.633_	_-1.506_	_-1.798_	_-1.467_	_-1.580_	_-1.650_	_-1.984_	_-1.976_	_-1.880_
ret23	0.004	0.005 *	0.002	0.005 *	0.005 *	0.005 *	0.005	0.008 *	0.005 *	0.006 *	0.003 *	0.002 *
	_1.456_	_1.888_	_1.552_	_1.948_	_1.636_	_1.830_	_1.237_	_1.943_	_1.780_	_2.053_	_1.829_	_2.711_
ret46	0.009 *	0.010 *	0.005 *	0.006 *	0.009 *	0.009 *	0.002 *	0.009 *	0.009 *	0.009 *	0.003 *	0.004 *
	_3.902_	_4.362_	_2.767_	_1.931_	_3.750_	_3.888_	_2.388_	_1.971_	_3.715_	_3.919_	_1.971_	_1.921_
ret712	0.006 *	0.006 *	0.001 *	0.003 *	0.006 *	0.006 *	0.003 *	0.006 *	0.006 *	0.006 *	0.008 *	0.005 *
	_3.719_	_4.103_	_2.296_	_2.069_	_3.522_	_3.658_	_1.889_	_1.889_	_3.653_	_3.792_	_1.921_	_2.041_
1/p	0.002 *	0.002 *	0.002 *	0.001 *	0.003 *	0.002 *	0.002 *	0.002 *	0.002 *	0.002 *	0.004 *	0.001 *
	_3.491_	_3.329_	_2.127_	_1.813_	_3.791_	_3.542_	_2.010_	_1.841_	_3.626_	_3.318_	_1.960_	_1.850_
measure		-0.001 *		0.000 *		0.001 *		0.000 *		0.001 *		0.001 *
		_-2.414_		_-1.956_		_2.433_		_2.902_		_2.497_		_2.150_

Table 4.2: Cross Sectional analysis of asset returns on firm fundamentals and volatility of liquidity

Panel B	S				RS				DVOL			
	Excess Return		Risk-adjust Return		Excess Return		Risk-adjust Return		Excess Return		Risk-adjust Return	
vol2	0.000	0.000	-0.001	0.000	0.000	0.001	0.000	0.000	-0.001 *	-0.001 *	0.000 *	-0.001
	-0.543	*-0.362*	*-0.391*	*-0.243*	*0.717*	*1.127*	*0.901*	*1.218*	*-1.777*	*-1.899*	*-1.856*	*-1.239*
cap	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001 *	0.000	0.000 *	0.000
	-0.826	*-0.434*	*-0.355*	*-0.455*	*-1.180*	*-0.871*	*-1.196*	*-0.997*	*-2.992*	*-0.106*	*-2.531*	*-1.414*
bm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001 *	0.001 *	0.001 *	0.001 *
	0.277	*0.341*	*0.514*	*0.521*	*0.416*	*0.396*	*0.844*	*0.495*	*1.661*	*1.843*	*1.852*	*1.759*
eps	0.007 *	0.007 *	0.004 *	0.003 *	0.007 *	0.007 *	0.003 *	0.003 *	0.007 *	0.007 *	0.002 *	0.002 *
	4.700	*4.536*	*1.832*	*2.252*	*4.855*	*4.802*	*2.715*	*1.826*	*2.326*	*2.434*	*2.300*	*2.148*
dy	-0.002	-0.002	-0.001	-0.008	-0.001	-0.001	-0.001	-0.006	-0.019 *	-0.024 *	-0.022 *	-0.094 *
	-0.219	*-0.278*	*-0.900*	*-0.873*	*-0.187*	*-0.196*	*-0.124*	*-0.211*	*-1.624*	*-2.413*	*-1.700*	*-2.604*
ret23	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.003	0.004	0.003	0.003
	0.208	*0.120*	*0.978*	*0.170*	*0.274*	*0.152*	*0.168*	*0.739*	*1.116*	*1.465*	*1.159*	*1.388*
ret46	0.008 *	0.008 *	0.002 *	0.006 *	0.008 *	0.008 *	0.005 *	0.009 *	0.009 *	0.009 *	0.006 *	0.005 *
	3.129	*3.198*	*2.675*	*1.803*	*3.120*	*3.192*	*2.700*	*1.981*	*3.681*	*3.956*	*1.931*	*1.940*
ret712	0.001	0.001	0.004	0.001	0.002	0.001	0.002	0.001	0.006 *	0.006 *	0.008 *	0.003 *
	0.694	*0.730*	*0.960*	*0.598*	*0.858*	*0.791*	*0.797*	*0.956*	*3.926*	*4.089*	*2.618*	*2.406*
1/p	0.004 *	0.005 *	0.009 *	0.006 *	0.004 *	0.004 *	0.010 *	0.004 *	0.003 *	0.002 *	0.008 *	0.007 *
	6.650	*6.641*	*2.405*	*2.711*	*6.233*	*5.910*	*1.960*	*2.740*	*3.665*	*3.551*	*2.602*	*2.242*
measure		0.001		0.001		0.000		0.000		-0.001 *	*	0.000 *
		1.251		*1.410*		*0.680*		*0.514*		*-1.818*		*-1.957*

Table 4.2: Cross Sectional analysis of asset returns on firm fundamentals and volatility of liquidity

Panel B (continued)	TR				RTODVOL				RTOTR			
	Excess Return		Risk-adjust Return		Excess Return		Risk-adjust Return		Excess Return		Risk-adjust Return	
vol2	-0.002 *	-0.002 *	-0.002 *	-0.001 *	-0.002 *	-0.001 *	0.000 *	0.000	-0.002 *	-0.001 *	-0.002 *	0.000
	-2.808	*-2.806*	*-1.950*	*-1.839*	*-1.827*	*-1.916*	*-1.947*	*-0.845*	*-2.655*	*-1.911*	*-1.927*	*-1.067*
cap	-0.001 *	-0.001 *	-0.001 *	-0.001 *	-0.001 *	-0.001 *	-0.001 *	-0.001 *	-0.001 *	-0.001 *	-0.001 *	0.000 *
	-3.280	*-3.530*	*-2.338*	*-2.056*	*-2.716*	*-2.335*	*-2.056*	*-2.187*	*-3.126*	*-2.599*	*-1.910*	*-2.663*
bm	0.001 *	0.001 *	0.000 *	0.000 *	0.001 *	0.001 *	0.000 *	0.000 *	0.001 *	0.001 *	0.000 *	0.000 *
	1.695	*1.890*	*1.922*	*1.810*	*1.628*	*1.875*	*1.844*	*1.869*	*1.698*	*1.908*	*1.978*	*2.226*
eps	0.007 *	0.007 *	0.003 *	0.002 *	0.008 *	0.009 *	0.004 *	0.009 *	0.008 *	0.009 *	0.004 *	0.005 *
	2.350	*2.444*	*2.759*	*2.580*	*2.832*	*3.377*	*2.653*	*1.966*	*2.568*	*3.162*	*2.339*	*2.216*
dy	-0.018	-0.023 *	-0.005	-0.018 *	-0.022 *	-0.031 *	-0.011 *	-0.008 *	-0.020 *	-0.030 *	-0.072 *	-0.026 *
	-1.526	*-2.328*	*-1.588*	*-2.169*	*-2.005*	*-2.953*	*-2.244*	*-1.976*	*-1.704*	*-2.686*	*-1.841*	*-2.728*
ret23	0.003	0.004	0.005	0.004	0.003	0.006 *	0.003	0.003 *	0.003	0.006 *	0.002	0.005 *
	1.081	*1.426*	*1.118*	*1.323*	*1.133*	*2.390*	*1.140*	*1.979*	*1.089*	*2.369*	*1.682*	*2.525*
ret46	0.009 *	0.009 *	0.005 *	0.004 *	0.009 *	0.010 *	0.001 *	0.008 *	0.009 *	0.010 *	0.008 *	0.011 *
	3.534	*3.853*	*1.974*	*1.975*	*3.732*	*4.502*	*2.063*	*1.817*	*3.628*	*4.395*	*2.789*	*2.784*
ret712	0.006 *	0.006 *	0.007 *	0.006 *	0.006 *	0.007 *	0.001 *	0.009 *	0.006 *	0.007 *	0.003 *	0.006 *
	3.779	*4.046*	*2.433*	*2.445*	*4.028*	*4.221*	*2.070*	*2.044*	*3.793*	*4.000*	*1.876*	*2.605*
1/p	0.003 *	0.002 *	0.003 *	0.009 *	0.002 *	0.002 *	0.003 *	0.002 *	0.003 *	0.002 *	0.002 *	0.002 *
	3.703	*3.566*	*2.753*	*2.011*	*3.708*	*3.418*	*1.815*	*1.935*	*3.832*	*3.525*	*2.768*	*1.971*
measure		-0.001 *		0.000 *		0.001 *		0.001 *		0.001 *		0.001 *
		-1.897		*-1.784*		*1.782*		*2.113*		*2.024*		*2.729*

Table 4.3: PCA results

The Panel A and Panel B report the percentage of cross-sectional variation explained by the first-three principal components of the volatility of liquidity, when liquidity is measured in six different measures respectively. The Principal components (PC) are extracted from all of the individual assets' volatility of liquidity. The liquidity variability Vol1 (Vol2) in month t as the standard deviation of daily liquidity levels in month t (prior 36 monthly liquidity levels) divided by the mean of daily liquidity levels in month t (prior 36 monthly liquidity levels), by equation (4.10) and (4.11). They are various when the liquidity is measured in six different measures: S, RS, DVOL, TR, R/DVOL, R/TR respectively. Apart from the principal components extracted from Vol1 (or Vol2) of single liquidity measure, the PC of Vol1 and Vol2 of across-measures are also displayed in the table. Across-6 measure indicates the first three components are extracted from a stacked matrix of all of the six Vol1 or Vol2 metrics using data from Jan., 1992 to Dec., 2011, while Across-4 measure indicates the first three components are extracted from a stacked matrix of all of the four Vol1 or Vol2 metrics (DVOL, TR, R/DVOL, R/TR) using data from Jan., 1962 to Dec., 2011. The Panel A and Panel B report the results from Vol1 and Vol2, respectively. The description of the systematic components of Vol1 and Vol2, which are extracted from all assets volatility of liquidity, are denoted as Vol1_j andVol2_j, where j indicates the liquidity measures S, RS, DVOL, TR, R/DVOL, R/TR and 6 or 4 stacked measures matrices.

Panel A

Vol1	**1st PC**	**2nd PC**	**3rd PC**	**SUM**
S	56.65%	9.56%	4.38%	70.58%
RS	56.44%	9.46%	4.40%	70.30%
DVOL	26.84%	16.20%	7.47%	50.51%
TR	27.58%	16.46%	7.44%	51.49%
R/DVOL	28.13%	20.47%	9.29%	57.89%
R/TR	28.09%	20.47%	9.29%	57.84%
Across-6 measure	37.71%	20.80%	7.11%	65.62%
Across-4 measure	45.45%	14.39%	6.75%	66.58%

Panel B

Vol2	**1st PC**	**2nd PC**	**3rd PC**	**SUM**
S	58.74%	15.60%	5.82%	80.16%
RS	59.00%	15.96%	5.93%	80.89%
DVOL	30.23%	17.43%	8.52%	56.17%
TR	29.27%	18.72%	8.86%	56.85%
R/DVOL	28.23%	22.52%	10.13%	60.87%
R/TR	30.05%	22.34%	9.87%	62.26%
Across-6 measure	41.07%	19.03%	10.01%	70.11%
Across-4 measure	45.44%	15.35%	7.56%	68.36%

Panel C

Vol1	**MEAN**	**MAX**	**MIN**
S	0.0549	0.1254	0.0119
RS	0.055	0.1284	0.0124
DVOL	0.039	0.0609	0.0135
TR	0.039	0.061	0.0137
R/DVOL	0.0395	0.0619	0.0159
R/TR	0.0396	0.0611	0.0157
Across-6 measure	0.0549	0.1268	0.0122
Across-4 measure	0.0508	0.0675	0.0225

Panel D

Vol2	**MEAN**	**MAX**	**MIN**
S	0.0619	0.122	0.0095
RS	0.0625	0.1121	0.0115
DVOL	0.0405	0.0647	0.0162
TR	0.0413	0.0568	0.0169
R/DVOL	0.0413	0.0587	0.015
R/TR	0.0416	0.0526	0.0167
Across-6 measure	0.0677	0.0955	0.0324
Across-4 measure	0.0516	0.0685	0.0218

Table 4.4: The post-ranking portfolio results

This table demonstrates the post-ranking portfolio results. Panel A, regarding the portfolios' summary statistics, provides the varies columns results of six liquidity measures respectively. The portfolios are formed and rebalanced monthly on the basis of estimations of systematic volatility of liquidity beta. In particular, being consistent with the results from Table 4.2 where the significant cross-sectional relationship between the asset return and volatility of liquidity, the estimation results of liquidity measures of S or RS are from equation (4.22) which considers Vol1, while the results regarding liquidity measures of DVOL, TR, R/DVOL and R/TR as well as two additional across-measures (across 4 or 6 liquidity measures) are obtained by equation (4.23) which involves Vol2. Portfolio 1 has the lowest beta of systematic volatility of liquidity, while portfolio 10 is most sensitive to the change of systematic volatility of liquidity. After the assets are sorted into the 10 portfolios, we calculate the value-weighted portfolio excess return and alphas from Fama-French three-factor model (FF-3). The size of each firms in portfolios are also reported the column of CAP. The differences of excess return and FF-3 alpha between portfolio 1 and 10 along with the t-statistics are in the last rows regarding each individual liquidity measure. Panel B displays the results of the risk premium of systematic volatility of liquidity with respect to six liquidity measure. In Panel B, the left part (columns 1 and 2) indicates the time-series mean return of the mimicking portfolio of the systematic volatility of liquidity factor. The mimicking portfolios are the product of the weights and the returns of base assets, where the weights of the assets are estimated from equation (4.26), and the base assets returns are the post ranking portfolios excess returns in Panel A. The columns 3-7 of Panel B is in terms of the estimations of the risk premium which are obtain by equation (4.28) and (4.29), the Fama-French three-factor models with additional systematic volatility of liquidity factor. The three risk factors in FF-3 are MKT, SMB and HML. The approach employed here is two-stage regressions, where the first stage is regarding the estimation of factor loading in rolling window regression, and the second stage is cross-sectional regressions using the estimations of beta from the first stage. Note that the liquidity measures of S and RS involves Vol1, and DVOL, TR, R/DVOL and R/TR as well as two additional across-measures involves Vol2. The results in columes 3-7 are the estimated coefficeints of lambda and the t-statistic are beneath the estimations. The last column of Panel A is the comparison of the mimicking portfolio returns and the estimation of risk premiums. The values in the last column are the ratios of the estimation of the risk premium of systematic volatility of liquidity over the mimicking portfolio returns, which indicates the estimation precisions.

Panel A

portfolio	S				RS				DVOL				TR			
	BETA_VOL1	excess return	CAPM alpha	CAP	BETA_VOL1	excess return	CAPM alpha	CAP	BETA_VOL2	excess return	CAPM alpha	CAP	BETA_VOL2	excess return	CAPM alpha	CAP
1	0.0447	0.0114	0.0498	3.6295	0.0016	0.0122	0.0493	3.6304	-6.3651	0.0135	0.2719	2.4839	-7.0930	0.0138	0.3009	2.5447
2	0.5360	0.0113	0.0208	4.6843	0.5042	0.0111	0.0198	4.6165	-3.2133	0.0130	0.1391	2.1169	-3.6665	0.0134	0.1557	2.1499
3	0.5662	0.0106	0.0168	4.7632	0.5174	0.0107	0.0174	4.7755	-1.6706	0.0125	0.0751	1.9179	-1.8415	0.0129	0.0783	1.8943
4	0.7069	0.0106	0.0100	4.6803	0.6331	0.0105	0.0099	4.6939	-0.8806	0.0124	0.0395	2.0477	-0.9426	0.0127	0.0398	2.1027
5	0.7704	0.0104	0.0033	4.1569	0.6937	0.0100	0.0035	4.2109	-0.3012	0.0122	0.0126	2.1049	-0.3582	0.0126	0.0142	2.1574
6	0.8330	0.0101	-0.0013	3.6399	0.7617	0.0100	-0.0006	3.6477	0.1388	0.0121	-0.0093	1.9503	0.1072	0.0125	-0.0080	1.9683
7	0.9211	0.0099	-0.0055	2.8818	0.8407	0.0100	-0.0048	2.8838	0.5051	0.0121	-0.0247	1.8465	0.5041	0.0123	-0.0235	1.8363
8	1.7025	0.0090	-0.0202	2.5632	1.5810	0.0090	-0.0188	2.5279	1.0500	0.0120	-0.0507	1.6432	1.0991	0.0120	-0.0486	1.5715
9	3.1982	0.0088	-0.0515	2.4417	2.9388	0.0086	-0.0477	2.4581	2.0464	0.0118	-0.1013	1.7848	2.1389	0.0116	-0.0993	1.7720
10	4.3348	0.0070	-0.0793	2.4451	3.7402	0.0069	-0.0680	2.4424	4.1899	0.0115	-0.1893	2.4571	4.1113	0.0115	-0.1902	2.3591
1-10		0.0044 *	0.1291 *			0.0053 *	0.1172 *			0.0021 *	0.4612 *			0.0023 *	0.4911 *	
		1.7235	3.9023			1.7854	2.3320			1.9723	3.2145			1.9982	2.6284	

portfolio	R/DVOL				R/TR				across-6 measure				across-4 measure			
	BETA_VOL2	excess return	CAPM alpha	CAP	BETA_VOL2	excess return	CAPM alpha	CAP	BETA_VOL2	excess return	FF alpha	CAP	BETA_VOL2	excess return	FF alpha	CAP
1	-5.1902	0.0138	0.2048	2.0554	-4.0855	0.0136	0.1695	2.2069	-1.4175	0.0131	0.1289	4.2991	-6.5025	0.0134	0.2773	2.1191
2	-2.5361	0.0136	0.0983	1.9913	-1.9071	0.0125	0.0774	2.1799	-1.0651	0.0117	0.1003	5.0625	-3.1525	0.0129	0.1339	2.0667
3	-1.2415	0.0135	0.0478	2.2615	-0.9069	0.0124	0.0354	2.1516	-0.9561	0.0115	0.0894	4.8352	-1.4910	0.0126	0.0630	2.0538
4	-0.6815	0.0131	0.0255	2.1436	-0.3967	0.0124	0.0146	2.0473	-0.8138	0.0113	0.0781	4.3274	-0.7114	0.0125	0.0290	2.0773
5	-0.3570	0.0131	0.0122	1.9025	-0.0848	0.0123	0.0023	1.9029	-0.7940	0.0109	0.0771	3.8146	-0.2889	0.0124	0.0111	1.9382
6	-0.1759	0.0125	0.0057	1.8470	0.1283	0.0123	-0.0059	1.8051	-0.7664	0.0105	0.0751	3.2608	0.2400	0.0122	-0.0130	1.8709
7	0.1518	0.0124	-0.0058	1.8721	0.4760	0.0120	-0.0189	1.8402	-0.6395	0.0104	0.0639	2.9364	0.6430	0.0120	-0.0292	1.8463
8	0.5398	0.0118	-0.0201	1.7992	0.9140	0.0120	-0.0363	1.6532	-0.2265	0.0101	0.0308	2.5992	1.2834	0.0118	-0.0570	1.8538
9	1.2905	0.0118	-0.0495	2.0385	1.9967	0.0119	-0.0820	2.1632	-0.0858	0.0086	0.0296	2.6072	2.6399	0.0115	-0.1200	2.1694
10	2.7869	0.0114	-0.1114	2.4456	4.2529	0.0115	-0.1830	2.4058	0.8879	0.0084	-0.0301	2.6571	5.2402	0.0115	-0.2425	2.3617
1-10		0.0024 *	0.3162 *			0.0022 *	0.3525 *			0.0047 *	0.1590 *			0.0020 *	0.5198 *	
		1.6724	3.2875			1.9924	3.2629			1.7825	3.2638			1.8348	2.5920	

Table 4.4: The post-ranking portfolio results

Panel B

liquidity measures	FVOL1(2)	constant	lambda MKT	lambda SMB	lambda HML	lambda FVOL1(2)	ratio
S	0.0087	0.0046	-0.0022	0.0099 *	0.0029	0.0066 *	76.09%
		0.8992	-0.3883	2.1129	0.5155	2.4896	
RS	0.0091	0.0069	-0.0067	0.0130 *	0.0023	0.0058 *	63.53%
		1.1044	-1.0152	2.6134	0.3664	1.7599	
TR	0.0033	0.0008	0.0050	0.0046 *	-0.0008	0.0018 *	54.35%
		0.1664	0.9728	2.1381	-0.2252	1.7194	
DVOL	0.0040	-0.0021	0.0108 *	0.0010	-0.0050	0.0026 *	66.77%
		-0.5048	2.4733	0.3966	-1.2332	2.8084	
R/DVOL	0.0032	0.0005	0.0055	0.0019	0.0004	0.0019 *	60.18%
		0.1069	1.1242	0.7049	0.0931	1.7516	
R/TR	0.0037	-0.0043	0.0087 *	0.0061 *	-0.0014	0.0035 *	94.43%
		-0.8121	1.6793	2.1767	-0.3431	2.9096	
ACROSS_6	0.0112	0.0044	0.0016	0.0145 *	0.0006	0.0076 *	67.20%
		0.9981	0.3007	3.4460	0.0803	2.3444	
ACROSS_4	0.0034	-0.0002	0.0037	0.0035 *	0.0026	0.0023 *	65.99%
		-0.0337	0.6919	1.6430	0.7003	1.9683	

Table 4.5: Correlation between mimicking factors and risk factors

This table present time-series correlations between the mimicking systematic volatility of liquidity factor and the FF-3 pricing factors. FVOL2_j, where j denote the liquidity measures dollar volume (DVOL), turnover ratio (TR), return to dollar volume (R/DVOL), return to turnover ratio (R/TR) or across these 4 liquidity measures or across all 6 liquidity measure, are the mimicking factor of systematic volatility of liquidity, and indicates the variation of liqiduiity over prior 36 months. The FVOL1_S and FVOL1_RS term the mimicking factor of systematic volatility of liquidity, and indicates the daily variation of liqiduiity within month, when the liquidity is measured by spread or relative spread. MKT, SMB, HML are FF-3 pricing factors, abridged for the returns of market portfolio, size mimicking portfolio and value mimicking portfolio.

	MKT	SMB	HML
FVOL1_S	0.340	0.321	0.106
FVOL1_RS	0.355	0.384	-0.037
FVOL2_DVOL	0.699	0.465	-0.049
FVOL2_TR	0.592	0.493	-0.057
FVOL2_R/DVOL	0.658	0.466	-0.049
FVOL2_R/TR	0.777	0.414	-0.074
FVOL2_across 4	0.632	0.438	-0.028
FVOL2_across 6	0.514	0.351	-0.074

Table 4.6: Statistic description of volatility of market-wide liquidity

This table reports the statistic description of volatility of market-wide liquidity. Mvol1 and Mvol2 are two types of volatility of liquidity: the type 1 volatility of liquidity represents the fluctuation of daily liquidity within month, while type 2 is essentially the coefficients of variation of monthly liquidity. They are calculated by equation (4.30) and (4.31), respectively. The mean, median, standard deviations are obtained by the time-series average of monthly cross-sectional mean, median, standard deviation. The market-wide liquidity is measured by six measurement, DVOL, S, RS, TR, R/DVOL and R/TR.

	MVOL1			MVOL2		
liquidity measures	Mean	Std	Median	Mean	Std	Median
S	0.0528	0.0570	0.0387	0.2039	0.1675	0.1166
RS	0.0508	0.0495	0.0401	0.2338	0.1817	0.1508
DVOL	0.1515	0.0639	0.1453	0.2131	0.0671	0.2063
TR	0.1583	0.0606	0.1498	0.2049	0.0827	0.1935
R/DVOL	0.1126	0.0416	0.1031	0.1876	0.0674	0.1623
R/TR	0.1183	0.0501	0.1030	0.1751	0.0642	0.1542

Table 4.7: Regressions results of volatility of market-wide liquidity factors

In this table, columns 1 and 2 indicates the time-series mean return of the mimicking portfolio of the volatility of market-wide liquidity factor, FMvol1 and FMvol2. The mimicking portfolios are the product of the weights and the returns of base assets, where the weights of the assets are estimated from equation (4.26) and the base assets returns are the excess returns of the post ranking portfolios, which are constructed based on the sensitivities of the asset returns to the volatility of market-wide liquidity. The columns 3-7 are in terms of the estimations of the risk premium which are obtain by equation from (4.28) and (4.29), the Fama-French three-factor models with additional volatility of market-wide liquidity factor. The three risk factors in FF-3 are MKT, SMB and HML. The approach employed here is two-stage regressions, where the first stage is regarding the estimation of factor loading in rolling window regression, and the second stage is cross-sectional regressions using the estimations of beta from the first stage. The results in columes 3-7 are the estimated coefficeints of lambda and the t-statistic are beneath the estimations. The last column is the comparison of the mimicking portfolio returns and the estimation of risk premiums. The values in the last column are the ratios of the estimation of the risk premium of volatility of market-wide liquidity over the mimicking portfolio returns, which indicates the estimation precisions.

Panel A

Market-wide liquidity	FMvol1	constant	lambda MKT		lambda SMB		lambda HML		lambda FMVol1		ratio
S	0.0009	0.0020	0.0061		-0.0039		0.0090		0.0005		
		0.2523	0.8072		-0.4275		1.3173		0.3880		
RS	0.0025	-0.0062	0.0153	*	-0.0109	*	-0.0071		0.0024	*	96.75%
		-0.8184	2.0334		-1.9945		-0.9613		1.7305		
DVOL	0.0132	-0.0036	0.0119	*	0.0074	*	-0.0010		0.0118	*	88.98%
		-0.7147	2.2932		2.3298		-0.3222		2.5204		
TR	0.0128	0.0068	0.0006		0.0000		-0.0043		0.0027		
		1.3204	0.1286		-0.0050		-1.2505		0.6501		
R/DVOL	0.0088	-0.0016	0.0101	*	0.0036		-0.0081		0.0069	*	78.44%
		-0.3044	1.9849		1.3633		-2.7301		2.1993		
R/TR	0.0090	-0.0004	0.0078		0.0007		-0.0004		0.0075	*	83.60%
		-0.0895	1.7231		0.2016		-0.1518		2.5874		

Panel B

Market-wide liquidity	FMVol2	ALPHA	lambda MKT		lambda SMB		lambda HML		lambda FMVol2		ratio
S	0.0208	0.0016	0.0126	*	0.0106	*	-0.0120	*	0.0266	*	127.67%
		0.4065	2.1588		2.0540		-1.6967		2.8707		
RS	0.0256	-0.0008	0.0094	*	0.0078	*	0.0068		0.0318	*	124.55%
		-0.1778	1.7879		2.2612		1.0829		2.4647		
DVOL	0.0202	0.0007	0.0058		0.0053	*	-0.0074	*	0.0099	*	49.12%
		0.1793	1.3828		2.2442		-2.2644		2.2639		
TR	0.0157	0.0062	-0.0005		0.0051		-0.0040		0.0057		
		1.3253	-0.0944		2.1173		-0.9531		1.2714		
R/DVOL	0.0132	0.0055	0.0046		0.0028		-0.0059		0.0033		
		0.9747	0.7667		0.6372		-1.3563		0.5969		
R/TR	0.0134	0.0060	-0.0007		0.0028		0.0007		0.0038		
		0.9453	-0.1168		1.2207		0.1646		0.6522		

Figure 4.1: The number of shares available in each month from Jan, 1962 to Dec. 2011.

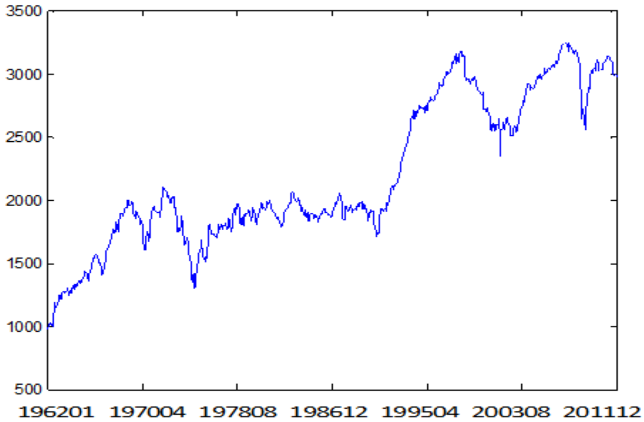
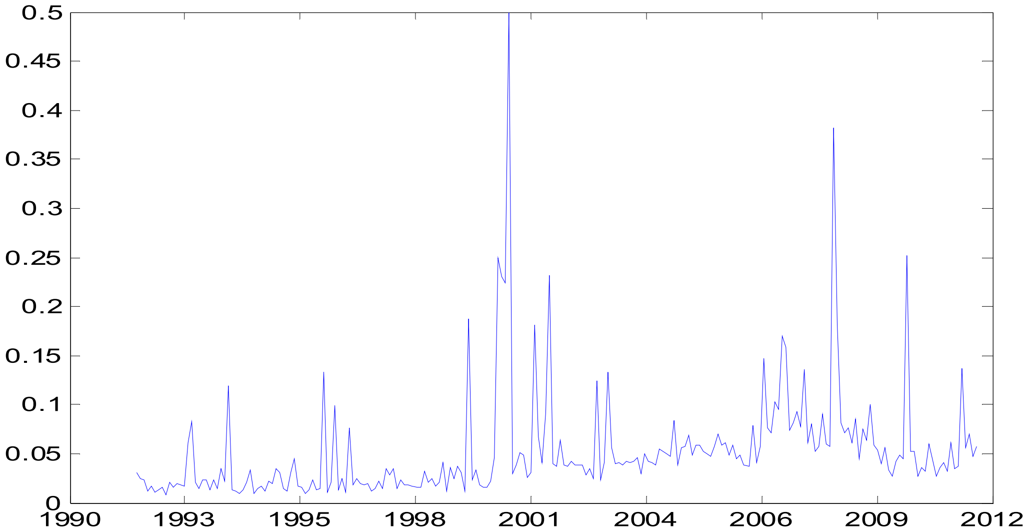
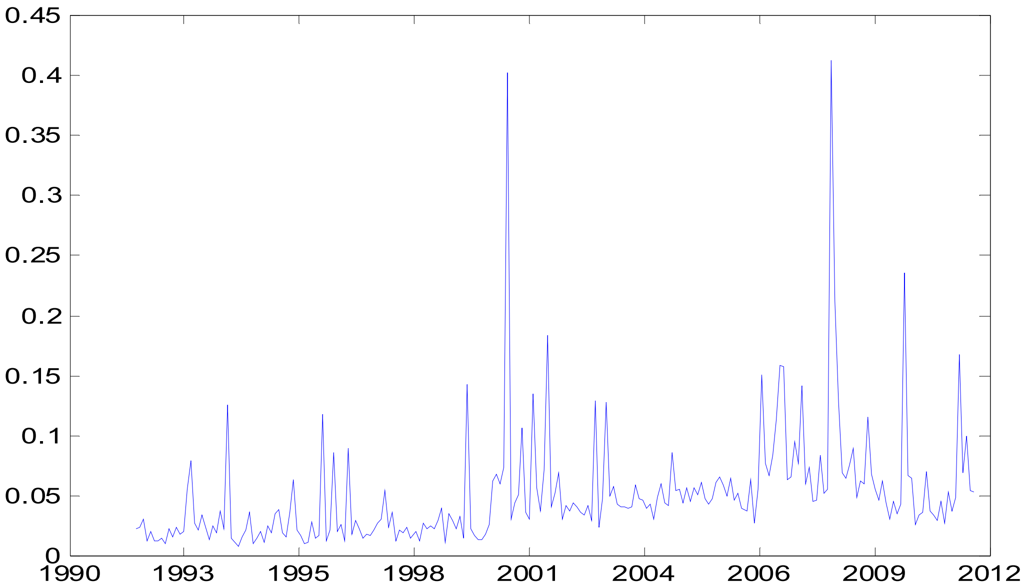


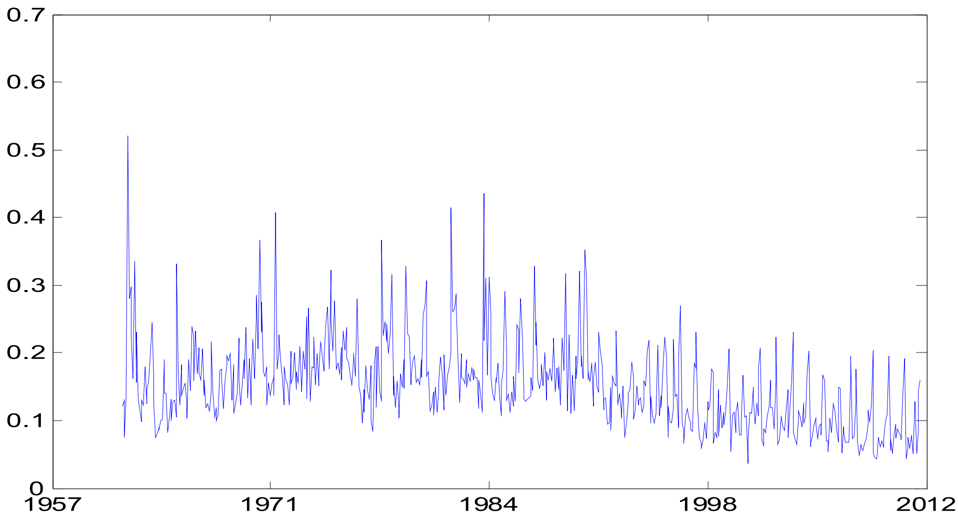
Figure 4.2: Time-series process of Mvol1, the type1 volatility of market aggregate liquidity by six liquidity proxies respectively.



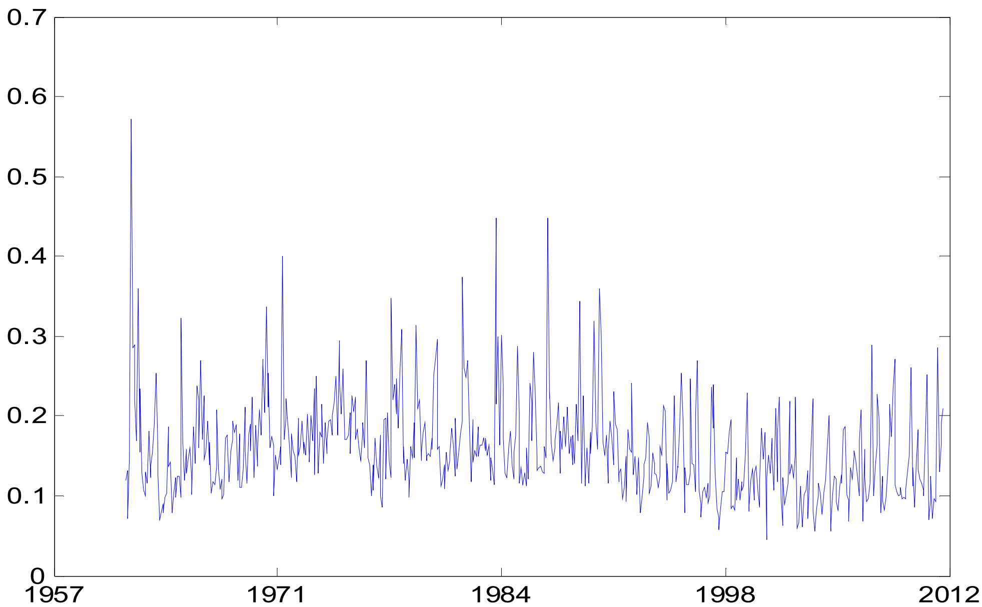
Mvol1_S



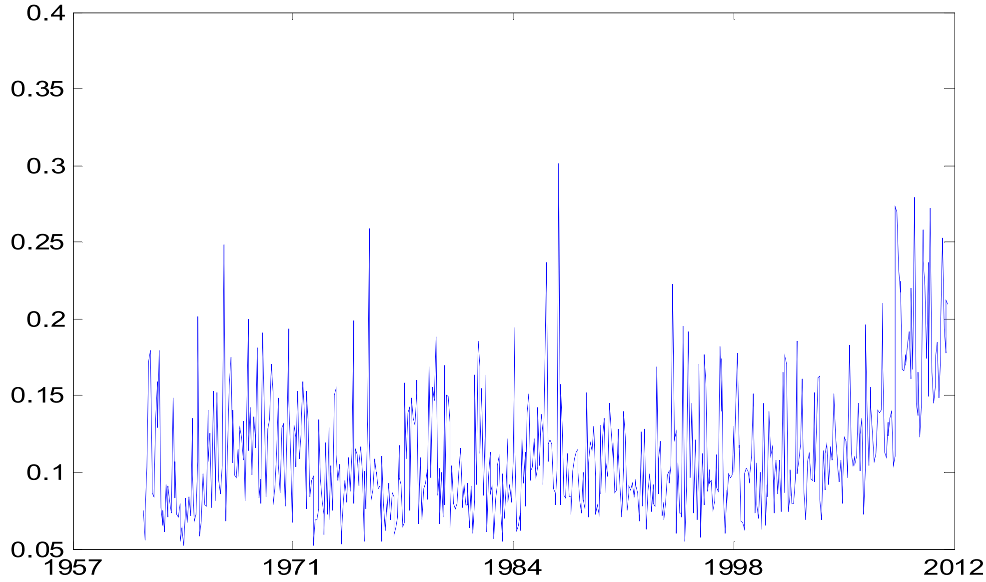
Mvol1_RS



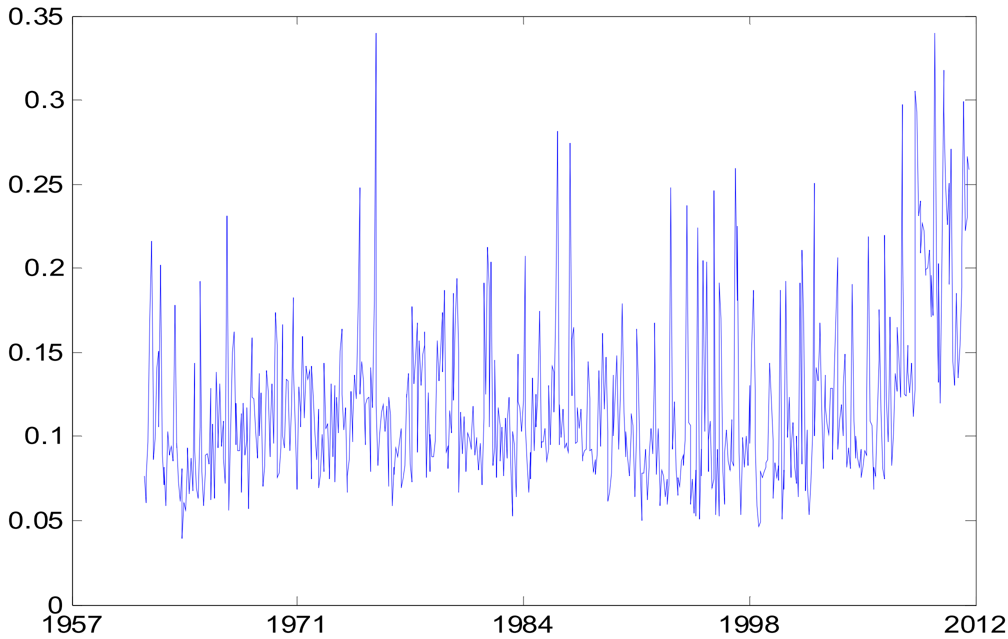
Mvol1_DVOL



Mvol1_TR

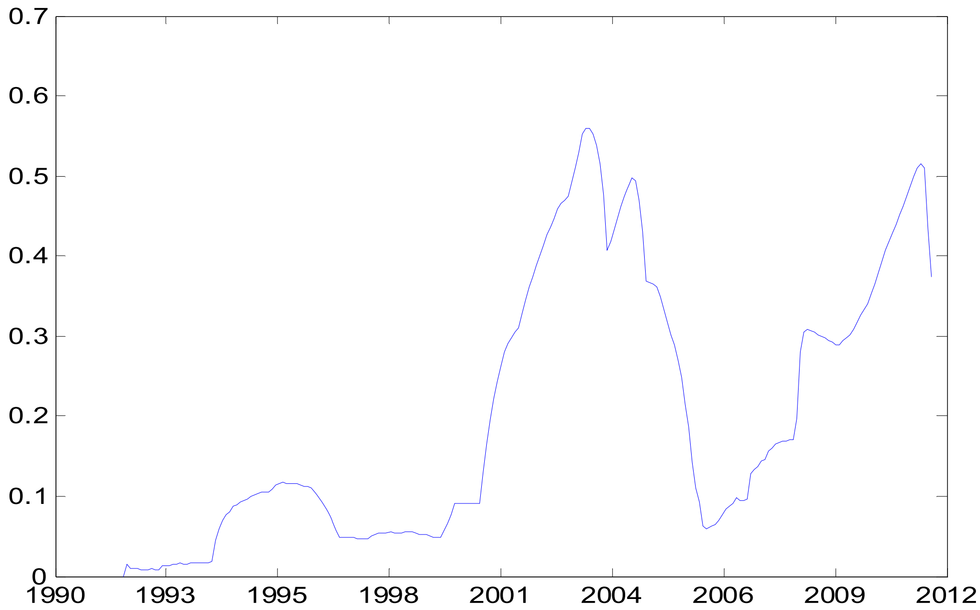


Mvol1_R/DVOL

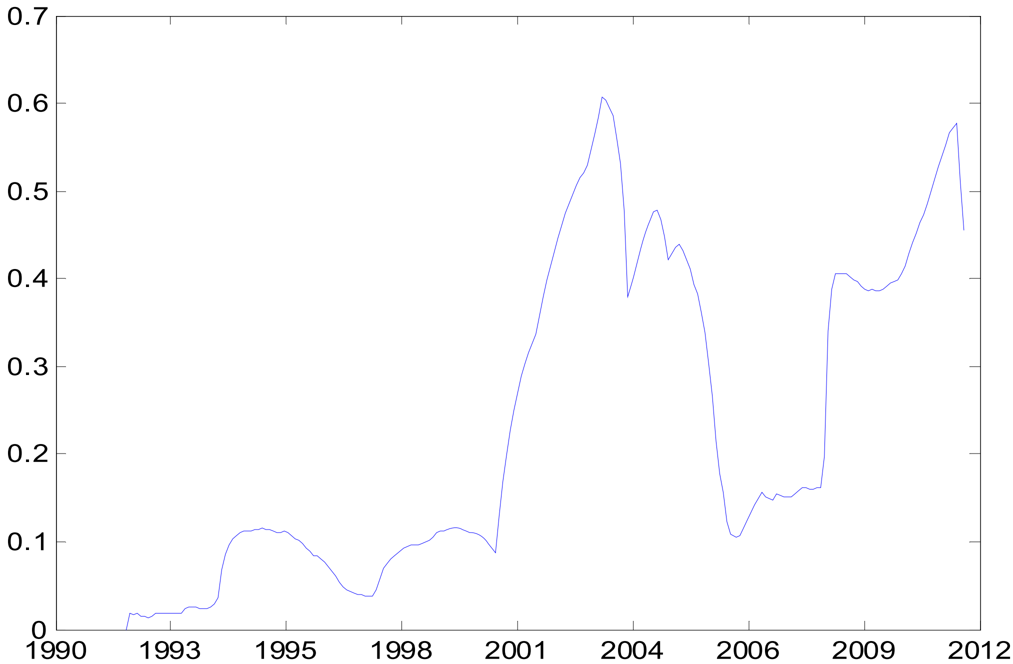


Mvol1_R/TR

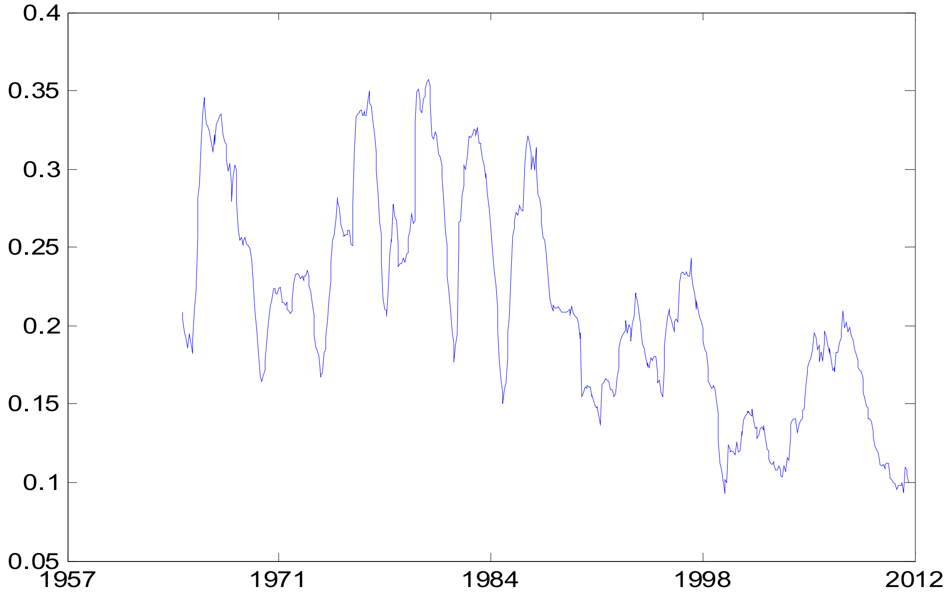
Figure 4.3: Time-series process of Mvol2, the type1 volatility of market aggregate liquidity by six liquidity proxies respectively.



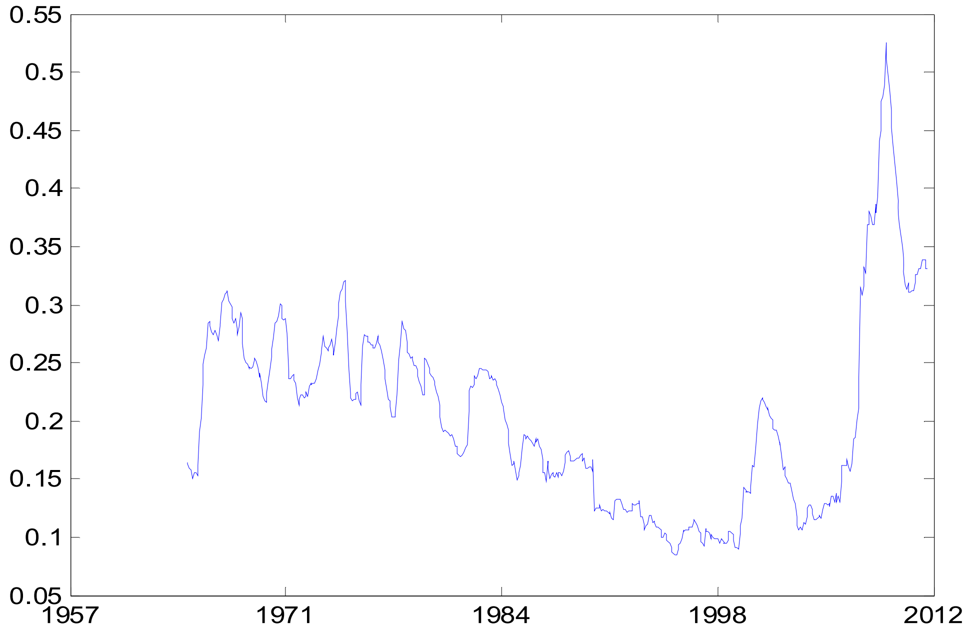
Mvol2_S



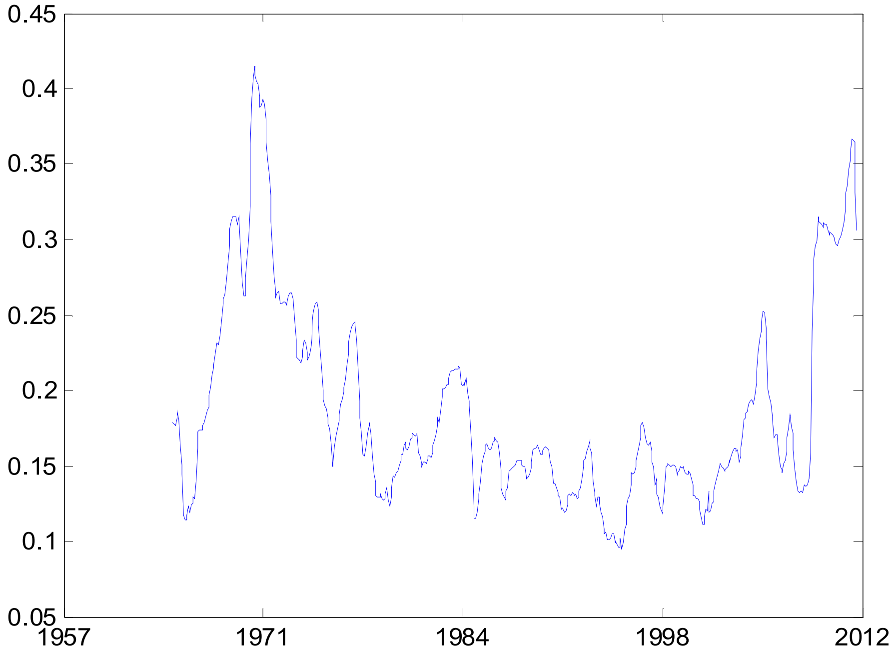
Mvol2_RS



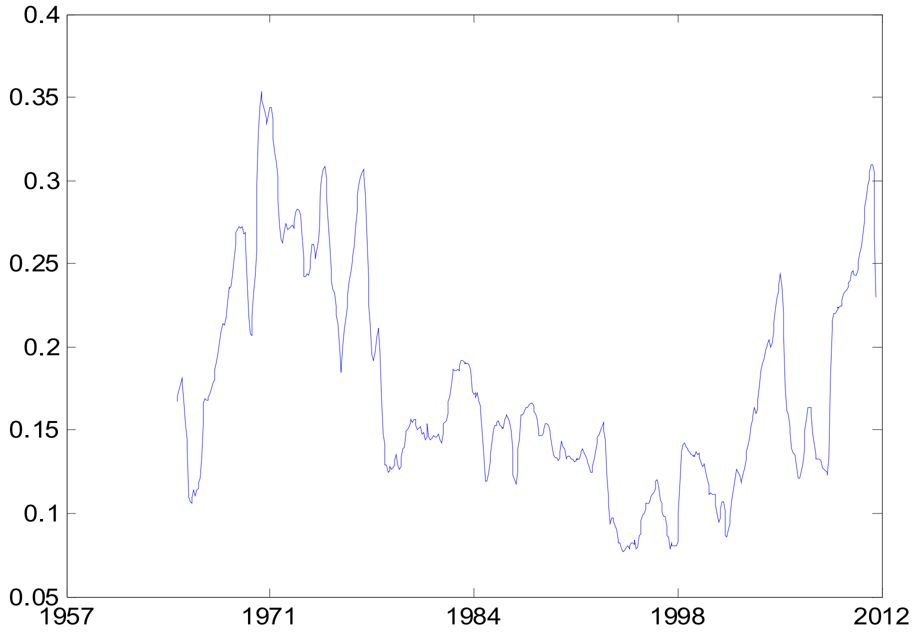
Mvol2_DVOL



Mvol2_TR



Mvol2_R/DVOL



Mvol2_R/TR

Chapter 5

The Volatility of Market Liquidity and Momentum Profit

Abstract

After identifying the impact of volatility of liquidity on asset returns, one is interested in its impact on momentum payoff. It is examined by investigating whether the volatility of market liquidity dominates the market liquidity level in terms of affecting and predicting the momentum profit. Besides, it is determined that the impact is state dependence with respect to the period of volatile verses illiquid; in particular, the impact of the fluctuation of the market liquidity on the momentum payoff is stronger when the market volatility or the illiquidity is higher. Finally, on closer inspection of the momentum crash event in 2009, it is observed that the volatility of market liquidity increases abruptly and sharply in the preceding period (a couple of months) before the crash, while stays stable during and after the crash.

5.1 Introduction

Momentum is pervasive in literature, of which the work of Jegadeesh and Titman (1993) is the most cited. Jegadeesh and Titman (1993) display a series of significant profits by a zero-cost trading strategy of buying past winner portfolios and selling past losers portfolios. This premium is consistent with the finding that the assets which perform well in the past few months would continue to be winners, and those have low returns tend to perform poorly for the next few months. However, the studies of stocks over periods of several years present an opposite pattern, that is, negative serial correlation of returns leads the long-term losers to outperform the long-term winners. Bondt and Thaler (1984) and Poterba, and Summers (1988) investigate the asset long-term reversals and explain this by return mean reversal and market overreation. DeBondt and Thaler (1985) provide stronger evidence of longer-term overreaction.

The momentum premium investigated by Jegadeesh and Titman (1993) has several features, including not being explained by conventional risk factors. Besides, the momentum profit is not consistently positive through the whole horizon; in particular, the returns of winner minus loser portfolio are negative during some periods (e.g., Brunnermeier, Nagel, and Pedersen (2008)).

The academic literature documents that the profit of momentum portfolio is closely related to the market conditions. For instance, momentum crash happens in rising market after downwards according to Daniel and Moskowitz (2014). Moreover, Cooper, Gutierrez, and Hameed (2004) and Wang and Xu (2010) also find that the momentum payoffs are lower when the market volatility is high. Recently, Avramov, Cheng and Hameed (2015) (hereafter ACH) provide evidence in their paper that the payoff of momentum portfolios crucially depends on the market illiquidity. ACH examine the impact of market illiquidity on momentum profit, finding lower momentum profit following illiquid market, and the higher momentum portfolio returns after relatively liquid market. Their finding is robustness and not explained by variation in macroeconomic condition, investor sentiment or by disposition-driven theory of momentum.

Several papers focus on the investigation of momentum premium and link it to liquidity. ACH (2015) claim that their finding is consistent with the overconfidence-illiquidity relation, conditional on the statement that the market illiquidity is the proxy of absence of overconfident investors, whose reaction causes return continuation. In illiquid market state, the reducing momentum payoff is partially from the market illiquidity and investors' little overconfidence, partially from the deterioration of loser stocks' liquidity, especially the illiquidity effect of losers exceeds the price continuation effect of winners. Pereira and Zhang (2010) discover that the investors trade less in illiquid market and more in liquid market, while the trading volume could be the proxy of investor's overconfidence, which leads to the positive momentum profit. Based on the results of Pereira and Zhang (2010) and ACH, one can conclude that there are heavier trading activities in liquid market and the following effect is higher momentum portfolios' profit. However, another recent paper of Chordia, Subrahmanyam and Tong (2014) presents the opposite conclusion. Chordia, Subrahmanyam and Tong (2014) connect momentum anomaly to market liquidity. Their study is based on the intuition that, in liquid market, increased arbitrage trading activities reduce equity return anomalies, including momentum payoff, especially after decimalization since 2001 when the trading cost is highly reduced and market liquidity increases. The opposite evidences between Chordia, Subrahmanyam and Tong (2014) and Avramov, Cheng and Hameed (2015) are puzzling. This highly raises our interest and I am strongly motivated to investigate the momentum following ACH (2015).

One may suggest that the volatility (or the fluctuation) of liquidity should be associated with momentum premium, and this idea comes from the finding of Pereira and Zhang (2010) which consider the trading strategies according to the states of market liquidity. Pereira and Zhang (2010) find a negative relationship between the stocks excess return and second moment of liquidity level, even after controlling for other stock characteristics. Pereira and Zhang (2010) explain the negative relation as the less required compensation for investors who hold the asset with higher liquidity volatility, since they can take advantage of the liquidity state to adjust the trading strategies, in order to take the trading opportunity when the liquidity volatiles. According to the empirical results in Chapter 4, I demonstrate the cross-sectional negative relationship between the expected return of asset and the volatility of liquidity; besides, I also provide evidence that the market-wide volatility of liquidity is significantly priced in the asset returns. On the other hand, the trading opportunity determines the trading strategy, and the asset pricing is, thus, linked to the momentum portfolio profit. Standing on the above facts, I am hence inspired to investigate the impact of volatility of market liquidity on momentum profit. More specifically, I am interested in investigating whether the volatility of liquidity dominates the liquidity in terms of affecting and predicting the momentum profit. Being different from ACH, who examine the momentum payoff based on time-varying market liquidity, I study variation of market liquidity and empirically tests the change of momentum profit in this study. Specifically, the motivation of this study is mainly originated from Pereira and Zhang (2010) that confirms liquidity variation is related to asset return and trading strategies, hence, potentially, it is reasonable to connect the momentum payoff to liquidity volatility. It seems that no consensus has been reached on the association between the volatility of liquidity and momentum payoff. Hopefully, the study on the volatility of liquidity might shed some light on this field.

In addition to the study regarding the impact of volatility of market liquidity on momentum profit, I am also sparkled to examine whether this relationship, which is between the volatility of market liquidity and momentum profit, exhibits state-dependent time variation. The study of Watanabe and Watanabe (2008) implies that the liquidity beta (the sensitivity of stock returns to market liquidity fluctuations) varies over time, especially the high liquidity-beta state is associated with the high market volatility and large trading activity, i.e. the liquidity-beta is not constant but state-dependent time varying. Therefore, I am encouraged to investigate in a scenario with two regimes "high volatile" periods and "normal" periods, differentiated by market return volatility, following Geyer and Ziemba (2008). For market liquidity, one could also categorize the whole sample periods into high and low market liquidity periods. I expect to obtain the time-varying impact of volatility of market liquidity on the momentum profit, whether it differs on the basis of the market volatility or the market liquidity.

Finally, I am highly interested in the momentum crash, as it is related to the market states. In a working paper, Daniel and Moskowitz (2014) study the two notable momentum crash periods, pre-WWII era and March to December 2009, when the profits from this "winner minus loser" strategy dramatically crashed, and the losers rebound dramatically and more quickly than the winners. Daniel and Moskowitz (2014) observe that before the momentum crashes periods, the market stress is high - it is the declining market with high volatility, and following that the crash occurs when the market raises and volatility reduces. In this thesis, providing the significant relationship between the volatility of market liquidity and the momentum profit, I am wondering whether the volatility of market liquidity or the market liquidity is linked to the momentum crashes. By other words, this thesis is built on Daniel and Moskowitz (2014) by following their methodology of event study, to observe the changes or patterns of market states variables[13], in my case, market liquidity and its volatility, around momentum crash periods. Being complementary to the study of Daniel and Moskowitz (2014) which discovers the possible signals of the oncoming momentum crash, this study may provide more precise prediction of the crash event. For investors, as long as the prediction of the momentum crash is accurate, the investors could reverse the

[13] As a matter of fact, I consider the possibility of the volatility of market liquidity is an indicator of the state of the real economy following the suggestion of Naes, Skjeltorp, and Odegaard (2011) which shows that the aggregate stock market illiquidity predicts the real economy.

traditional momentum strategy to make profit, which is, buying past losers and shorting past winners instead.

The objectives of this chapter is to investigate the momentum-volatility of liquidity relationship in presence of other market states, and examining whether this relationship exhibits state-dependent time variation, especially under different market regimes of volatility and liquidity, as well as studying whether the market liquidity and its volatility are linked to the "momentum crash".

The rest of this chapter is organized as follows; Section 5.2 explains the dataset and Section 5.3 provides the research methodology, Section 5.4 presents the empirical findings and the last one concludes the chapter.

5.2 Data

The dataset contains all common shares listed on NYSE-AMEX from CRSP and the sample spans from Jan., 1962 to Dec., 2011. The variables of firms are closing price, trading volume, share of outstanding, and return at daily frequency. Unlike the data sample used in the previous two chapters, it is not required that the stocks in the sample must have more than 2 years prices or more than 15 trading days in one month, but it is required that the stocks should have more than 8 months data over the prior 11 months in order to construct the momentum portfolios, following Avramov, Cheng and Hameed (2014). Besides, I collect fewer data variables than previous two chapters, because it is not required those shares have valid data of bid/ask price, book value, earning per share, dividend yield; therefore, fewer firms are filtered out than the previous two chapters.

The daily data from CRSP are transformed into monthly security characteristics by averaging or summing, in order to obtain monthly returns, trading volume, share of outstanding and market capitalization. The statistics description of monthly fundamental variables, obtained by the time-series averages of the cross-section, is reported in Table 5.1 Panel A. CAP is the market capitalizations of firms. RET is the monthly return of assets. PRICE denotes the closing prices at the end of month. DVOL is firms' monthly dollar volume, and calculated by multiplication of trading volume and PRICE.

Besides, using the collected date, one could further compute the shares' liquidity by Amihud measure (return to dollar volume), $illiq_{i,t} = R / DVOL_{i,t} = \frac{1}{n}\sum_{t=1}^{n}(\frac{|RET_{i,d}|}{DVOL_{i,d}})$, where i is the asset indicator, d and t stand for the day and month indicators and n is the number of available trading days in each month, and the return to dollar volume is the ratio of the average absolute return over the dollar volume, over month m. The market aggregate illiquidity, $MLIQ_t$, is obtained as the equal-weighted average of the individual shares' illiquidity by Amihud measure $illiq_{,t}$, while the volatility of market liquidity (or illiquidity), $MLIQVOL_t$ is the coefficients of variation of monthly market illiquidity, that is, the standard deviation of prior 36 monthly market aggregate illiquidity levels divided by the mean of prior 36 monthly illiquidity levels.

$$MLIQVOL_t = \frac{\sigma_t}{\mu_t} = \frac{\sqrt{\text{var}(MLIQ_t)}}{\frac{1}{36}\sum_{t-36}^{t-1} MLIQ_t} \tag{5.1}$$

where σ_t is the standard deviation of the prior 36 monthly liquidity levels of market, and μ_t is the mean of the prior monthly liquidity observations.

Apart from $MLIQ_t$, $MLIQVOL_t$, there are more market states variables as the explanatory variables i.e. $DOWN_t$, and $MVOL_t$, as well as the Fama-French risk pricing factors

MKT_t, SMB_t, HML_t for time-series and cross-sectional regressions. $DOWN_t$ represents the market directions of downwards, signified by the dummy variable indicating the market trend, taking the value of one if the prior 24 months cumulative returns of the value-weighted market portfolio is negative or zero if the cumulative returns is non-negative. $MVOL_t$ is denoted as market volatility, implying the fluctuation of the market return. $MVOL_t$ is calculated by the standard deviation of daily value-weighted CRSP market index returns over the month. The US Fama-French factors MKT_t, (excess return on the value-weighted CRSP market index over the one-month T-bill rate), size factor SMB_t (small minus big return premium) and value factor HML_t (high book-to-market minus low book-to-market return premium), are downloaded from the website French's library. In the regressions, the response variable is the momentum portfolio returns, Mom_t, which is from the trading strategy of buying past winner portfolio and selling past loser portfolio. In particular, in order to construct the momentum portfolios, I first rank stocks according to the cumulative returns from 12 months before to 1 month before the formation date (e.g., t − 12 to t − 2). One month gap is considered for the purpose of avoiding the short-term one-month reversals according to Jegadeesh (1990) and Lehmann (1990). All of the stocks are allocated to the one of ten decile portfolios based on this ranking, and the stocks with the highest cumulative returns from t − 12 to t − 2 are in the winners group, while those with the lowest cumulative returns are in the losers portfolio. Note that the portfolios are rebalanced at the monthly basis. Thus, the differences between the winners portfolio and the losers portfolios are computed as the momentum profit.

The statistics description of these regression variables are displayed in Panel B of Table 5.1. The correlation matrix among the regression variables are in Panel C of Table 5.1. Clearly, the correlation between the momentum payoff and the volatility of market liquidity is negative according to the matrix.

5.3 Methodology

5.3.1 Impact of Market States on the Momentum Profit

5.3.1.1 Time-series Test

Our investigation is based on the following time-series regression:

$$Mom_t = \alpha + \beta_1 MLIQVOL_{t-1} + \beta_2 DOWN_{t-1} + \beta_3 MVOL_{t-1} + \beta_4 FF_t + \beta_5 MLIQ_{t-1} + \varepsilon_t \quad (5.2)$$

where Mom_t is the momentum portfolio return which is the difference between winner's and loser's return, and the winner/loser portfolios are constructed by sorting stocked into 10 deciles from month t-12 to t-2. $MLIQVOL_{t-1}$ is the volatility of market illiquidity, following the definition in Chapter 4, I construct the volatility by the coefficients of variation of monthly liquidity, that is, the standard deviation of prior 36 monthly liquidity levels divided by the mean of prior 36 monthly liquidity levels. $DOWN_{t-1}$ is dummy variable indicating the market trend, taking the value of one if the prior 24 months cumulative returns of the value-weighted market portfolio is negative or zero if the cumulative returns is non-negative. $MVOL_{t-1}$ is denoted as market volatility, the standard deviation of daily value-weighted CRSP market index returns over the month. FF_t is Fama-French pricing factors (MKT, HML, and SMB). I also include the market illiquidity

$MLIQ_{t-1}$ as the independent variable, obtained by the equal-weighted average individual assets' illiquidity, which is represented by Amihud (2002) measure (R/DVOL).

The momentum payoff is regressed on the sub-sets of market state variables in the time-series scale. Since the main objective in this chapter is going to investigate the role of volatility of market illiquidity, $MLIQVOL_{t-1}$, on prediction of momentum payoff, I include $MLIQVOL_{t-1}$ in all regression specifications. To illustrate, in Model 1, the independent variables are $MLIQVOL_{t-1}$ and three risk factor variables FF_t. In Model 2 and 3, I add additional market state variables, $DOWN_{t-1}$ and $MVOL_{t-1}$, respectively. Furthermore, I include the both variables in Model 4. Finally, the all-variables-included regression is based on Model 6, which considers market illiquidity, $MLIQ_{t-1}$, on the basis of the empirical results of ACH.

5.3.1.2 Cross-sectional Test

After the investigation of the relationship between momentum profit and volatility of market liquidity in the time-series scale, it follows the examination in cross-sectional dimension. In particular, I not only study the momentum and extreme winner/loser portfolios, but also attempt to examine the individual assets.

Following the method of ACH, the examination is based on a two-stage analysis. The first stage is in order to estimate the cross-sectional assets' momentum effect. Specifically, in the monthly cross-sectional regressions, the individual asset return are regressed on the explanatory variables: the past cumulative return, the past cumulative negative return and the firm level volatility of liquidity, $LIQVOL_{i,t}$. I include the variable $LIQVOL_{i,t}$ in the regressions based on one of the empirical results from Chapter 4, which is the negative cross-sectional relationship between firm return and its volatility of liquidity, and the usage of this variable could account for the volatility of liquidity effect. Thus, the cross-sectional regression is:

$$R_{i,t} = \alpha + \beta_{1,t} R_{i,t-12:t-2} + \beta_{2,t} R^{-}_{i,t-12:t-2} + \beta_{3,t} LIQVOL_{i,t-1} + \varepsilon_{i,t} \tag{5.3}$$

where $R_{i,t}$ is the stock return in month t, $R_{i,t-12:t-2}$ is the cumulative return from months t-12 to t-2, and $R^{-}_{i,t-12:t-2}$ is the cumulative return if the return is negative or zero otherwise. $\beta_{1,t}$ indicates the firm level momentum effect of stock i in month t, while $\beta_{2,t}$ implies the additional marginal momentum effect. The cross-sectional regressions are implemented on monthly basis.

The second stage involves the time-series regressions. The obtained cross-sectional momentum effect coefficients are, respectively, regressed against the market state variables, volatility of market liquidity, market illiquidity, DOWN market state, and market volatility:

$$\beta_{1,t} = \alpha + \kappa_1 MLIQVOL_{t-1} + \kappa_2 MKTLIQ_{t-1} + \kappa_3 DOWN_{t-1} + \kappa_4 MKTVOL_{t-1} + \varepsilon_t \tag{5.4}$$

$$\beta_{2,t} = \alpha + \kappa_1 MLIQVOL_{t-1} + \kappa_2 MKTLIQ_{t-1} + \kappa_3 DOWN_{t-1} + \kappa_4 MKTVOL_{t-1} + \varepsilon_t \tag{5.5}$$

By the time-series regressions results, I could obtain the estimations of the slopes of the market states variable, κ_1, κ_2, κ_3 and κ_4. In particular, the slope κ_1 is the main interest in this chapter, because it represents the dependence of individual firm momentum effect on the volatility of market liquidity. Being different from the above method in Section 5.3.1.1 which is working on the investigation of relationship between momentum profit and volatility of market liquidity, I am attempt to examine the impact of volatility of market liquidity on individual momentum coefficients, that is, price continuation effect.

5.3.2 State Dependence: the Impact of Volatility of Market Liquidity on Momentum Profit

In order to illustrate the differential impact of the volatility of market liquidity on momentum profit, I conduct a set of monthly time-series regressions as following:

$$Mom_t = (\alpha + \alpha' I_{vol}) + (\beta_1 + \beta_1' I_{vol}) MLIQVOL_{t-1} + \beta_2 MLIQ_{t-1} + \beta_3 DOWN_{t-1} + \beta_4 MVOL_t + \beta_5 RM_t + \beta_6 HML_t + \beta_7 SMB_t + \varepsilon_t$$

(5.6)

$$Mom_t = [\alpha + I_{vol}(\alpha' + \alpha'' I_{liq})] + [\beta_1 + I_{vol}(\beta_1' + \beta_1'' I_{liq})] MLIQVOL_{t-1} + \beta_2 MLIQ_{t-1} + \beta_3 DOWN_{t-1} + \beta_4 MVOL_t + \beta_5 RM_t + \beta_6 HML_t + \beta_7 SMB_t + \varepsilon_t$$

(5.7)

Apart from the variables used in equation (5.2), the additional variable in equation (5.6) is, I_{vol}, indicator variable of market state of volatility. It equals one if the market volatility is in a high state, i.e., the specific month is during the "high volatile" periods, and zero otherwise. Moreover, in equation (5.7), I further introduce the indicator variable, I_{liq}, as the instrument, which equals one if the market liquidity is in low state, and zero otherwise. This specification is an attempt to capture the differential betas of both the momentum portfolio and the volatility of market liquidity in volatile and illiquid markets. Specifically, I consider two regimes such that 30% of the months the markets are high volatile and 70% of the month the markets are normal, on the basis of market volatility; meanwhile, there are 50% high range and 50% low range based on the market liquidity level. Both of the instrumental indicators are for contemporaneous market states, and the indicator variables I_{vol}, and I_{liq} are thus sequences of ones and zeros; in particular, 30% of I_{vol}, and 50% of I_{liq} are sequences of only ones.

Providing that the two time-series sequences of zeros and ones could indicate the states of market volatility and liquidity, regressions based on equation (5.6) and (5.7) and estimate the coefficients, β. Therefore, the sum of two coefficient estiamtion of market liquidity volatility, ($\beta_1+\beta'_1$), would present the impact of the volatility of market liquidity on momentum profit, in high volatile market state where the values of I_{vol} are ones. Similarly, the point estimation of ($\beta_1+\beta'_1+\beta''_1$) indicates the relationship between $MLIQVOL_{t-1}$ and Mom_t, when the market volatility is high and market liquidity dries up (illiquid market state) when I_{vol}, and I_{liq} are all ones. The estimation results from the sets of time-series regression are displayed in Table 5.4.

5.3.3 Momentum Crash

Daniel and Moskowitz (2014) put two "momentum crash" periods, under closer scrutiny, namely, the Great Depression (1932 to WWII era) and March to December, 2009. They find that each crash is predictable by the market stress - the market has fallen and the market volatility has been high, especially when the contemporaneous market returns rise after the declining period. In other words, before the crashes, the market return falls and the volatility is high, while when the crashes occur, the market return raises up and the volatility is reduced. During the momentum crash periods, the underperformance of the strategy is attributable to the strong reversal of loser portfolios, of which the returns could be couple of times of the winner portfolios. By close investigation, they find that the source of crash is from the optionality of market beta of loser and winner firms in bear and up market. In particular, the loser portfolios' beta is higher than winners. Therefore, the returns of losers rebound quicker than winners in up market, and the momentum crash occurs.

Due to the limited length of the data, this chapter could only study the case of momentum crash period in 2009. Apart from the aforementioned phenomenon of market return and volatility before and during crash period, it is observed that the market liquidity and the volatility of market liquidity could also be the signs for the impending crash. Specifically, the market liquidity level is significantly reduced at the end of 2008, and ameliorated dramatically after one year which is the end of the momentum crash period. As for the volatility of market liquidity, it rises by twice of the normal level a few months before March, 2009; from March to December, the volatility of market liquidity stays relatively stable. The limitation is further explained in Section 5.5.4.

5.4. Empirical Results

5.4.1 Impact of Market States on the Momentum Profit

5.4.1.1 Time-series Test

In Panel A of Table 5.2, the regression results of equation (5.2) are reported. The market states variables are regressed on the momentum portfolio returns. I find that the slopes of $MLIQVOL_{t-1}$, the estimated coefficients β_1, are significant and negative in most of the regression models. It is -7.083 in model 1, which includes Fama-French factors in the regression. The coefficients β_1 are significant from model 3, 4, 6 which add $MVOL_{t-1}$, $DOWN_{t-1}$ and $MLIQ_{t-1}$ in the regression, and the estimations range from -6.749 to -8.121. However, the estimation in model 2 is insignificant. The negative relation indicates that the momentum payoff decreases following increasing volatile market illiquidity (or liquidity), while after the stable market illiquidity periods, the momentum profits are higher.

The empirical results of negative relationship between momentum payoff and the volatility of liquidity have its economical meaning. Considering the difficulty to manage and predict the market liquidity state, the high volatility of market liquidity could be recognized as the indicator of the absence of overconfident investors. In particular, Armstrong at al (2010) and Barinov (2014) claim that in volatile liquidity states, due to the firms' idiosyncratic risk, the liquidity level tends to become below mean, i.e. when the market liquidity fluctuates heavily, the market inclines to be illiquid instead of liquid. On the other hand, according to ACH, low market liquidity is associated with decreasing momentum payoff as a result of disappearance of overconfidence in illiquid market state. Since the price continuation is led by the market overconfidence, it makes sense that the momentum payoff is connected to the volatility of market liquidity.

Moreover, apart from the negative association between the momentum payoff and the volatility of market liquidity, the contribution of other market states to the momentum profit is rather compelling. First of all, according to the results of Model 6, coefficient of $MLIQ_{t-1}$ turns out to be insignificant (the estimate slope of $MLIQ_{t-1}$ in ACH 2014 is significant, but they do not consider $MLIQVOL_{t-1}$ in their study) when the variable of $MLIQVOL_{t-1}$ is included in the right-hand side, while the estimated coefficients of $MLIQVOL_{t-1}$ are significantly negative. Based on this finding, I conjecture that the volatility of market liquidity may dominate the market liquidity in terms of predicting the momentum payoff. Besides, the estimated coefficient of market return state, $DOWN_{t-1}$, is insignificant except in Model 2, while the slope of $MVOL_{t-1}$ is significant and negative in all of the model regressions, and this implies that in high volatile market, the following momentum strategy fails to make large profits. In each regression, the coefficients of Fama-French factors are negative estimations, and it is in line with literature.

The above regression specifications on the winner and loser portfolio's return are also put under further study. The results are displayed in Panel B and C of Table 5.2. Specifically, I find that the slopes of $MLIQVOL_{t-1}$ are significantly negative for the winner portfolio returns but insignificant for losers. That is, the winner portfolios' return declines following unstable market illiquidity state, while losers are not affected by the fluctuation of market liquidity. It implies that the predominant source of reducing momentum profit after the volatile market liquidity turns out to be the winner portfolios. In this sense, considering the negative relationship between asset return and its volatility of liquidity in the cross-sectional dimension, i.e. the investors require lower expected return as compensation when the asset's liquidity level is more volatile, one could explain the decreasing momentum profits during volatile market liquidity periods as the lower expected asset return, which, in turn, is revealed as a lower payoff in momentum strategy.

Regarding the effect of market volatility on the winner and loser portfolio's returns, the negative coefficients of $MVOL_{t-1}$ estimated from winner portfolio regressions and the positive counterpart from the loser portfolios are rather indicative - the past winner portfolio returns drop in volatile market, while the past loser portfolio returns increase. Besides, $MLIQ_{t-1}$ is positively related to the past winner portfolio return and insignificantly contributed to the loser portfolio return. This finding contradicts the results in ACH, however, it possibly could be due to the introduction of additional market state variable $MLIQVOL_{t-1}$. Withal, the $DOWN_{t-1}$ variable is insignificant in most of the regressions.

5.5.1.2 Cross-sectional Test

In order to investigate the impact of volatility of market liquidity on the momentum profit in the individual firm level, I follow the methodology of ACH. Basically, I evaluate the firm level momentum effect by the cross-sectional regressions, which is the coefficient estimation of firms' past cumulative returns. In addition, I take the momentum coefficients as the dependent variable, and the slopes of market states variables from the regression estimation would represent the impact of market states on the momentum profit at the individual firm level.

The estimation coefficients of momentum effect are displayed in Penal A of Table 5.3. When the past cumulative returns and the firm level volatility of liquidity are included as the explanatory variables, the monthly cross-sectional regressions give us the time-series mean of slopes. The empirical results provide individual security level evidence of both a strong price continuation and the significant volatility of liquidity effect in stock returns, in the cross-sectional dimension. Specifically, the mean slope of $R_{i,t-12:t-2}$ is significantly positive, and it implies that the momentum effect on firm level price is positive, after controlling the negative effect from firm volatility of liquidity. In particular, the estimation of β_1 is 0.014 with t-statistic 2.1905. Moreover, in model 2, I include one more explanatory variable in the Fama-MacBeth regressions, $R^{-}{}_{i,t-12:t-2}$, the variable of negative past cumulative returns. The finding is that the time-series mean of slopes of this variable β_2 is 0.0182, and it indicates that the price continuation of past losers' behavior is even stronger than overall. Additionally, the slope coefficient of the firm's volatility of liquidity controlling variable is significantly negative in both specifications, consistent with fact that those stocks with low volatile liquidity earn higher future returns than others.

Furthermore, I conduct the regression of the time-series slope $\beta_{1,t}$, which presents the momentum effect, on individual shares level, on the one-month lag market state variables. The results are displayed in Table 5.3, and one can see that the coefficient of volatility of market liquidity, $MLIQVOL_{t-1}$, is -1.4587. However, the slopes of $MLIQ_{t-1}$ and $DOWN_{t-1}$ are insignificant and it means their productivity disappears in the presence of other states variables, but the predictive power of $MVOL_{t-1}$ persists (-1.8735 with t-statistics -1.9294) as the finding from Penal B of Table 5.3.

The regression results from $\beta_{2,t}$, which is the stock level momentum coefficient following negative past returns, are similar to those from $\beta_{1,t}$. Specifically, the estimation slope of $MLIQVOL_{t-1}$ is -2.9645, which suggests decreasing momentum effect in volatile market liquidity condition, and this effect is even stronger in the month after negative past returns than other periods. The results of the slopes estimation of other market states are also similar with the regression estimation from model 1 - the predictive power of $MLIQ_{t-1}$ and $DOWN_{t-1}$ fades with the existence of $MLIQVOL_{t-1}$ and $MVOL_{t-1}$.

En masse, the significant and negative coefficients of $MLIQVOL_{t-1}$ obtained from all of the above time-series and cross-sectional regressions suggest that the high volatility of liquidity leads to the reduction of momentum effect, otherwise, when the market liquidity level stays stable, the price continuation is stronger. This conclusion applies to the momentum both on portfolio and individual firm level.

5.5.2 State Dependence: the Impact of Volatility of Market Liquidity on Momentum Profit

As aforementioned, in order to investigate the potential time-varying effect of volatility of market liquidity on the momentum profit, one can introduce the indicator variables as the instruments, I_{vol} and I_{liq} , into the original models. In particular, I_{vol} equals one if the volatility of market returns in month t is relatively high, and it is zero otherwise, in addition, the percentage of ones and zeros sequence of I_{vol} is 30% and 70%, respectively. Meanwhile, I_{liq} is one if the market is illiquid and zero otherwise, and half of the I_{liq} sequence are ones and zeros.

One of the emphasis of this chapter is on the coefficients of $MLIQVOL_{t-1}$. The coefficients, β_1, β_1' and β_1'', which document the relationship between the volatility of market liquidity and the momentum profit, especially in the volatile and illiquid regime. First of all, the estimation results from equation (5.6) are in column 3 and 4 of Table 5.4, where the point estimation of β_1 is insignificant and β_1' is -9.33. This implies that the coefficients of $MLIQVOL_{t-1}$ change remarkably in the periods of volatile market and there is -9.33 lower with a t-statistics of -3.9 on the difference. Moreover, the results of regression equation (5.7) in column 5 and 6 present the extent to which the coefficients of $MLIQVOL_{t-1}$ differ in liquid and illiquid market state. The estimation of β_1' indicates that, in months of liquid market, the coefficient of $MLIQVOL_{t-1}$ is -6.21 with a t-statistics of -1.998, while in the period of illiquid market, the coefficient of $MLIQVOL_{t-1}$ is -14.45 which is the sum of β_1' and β_1'' estimation.

The summaries from the empirical results are as follows: the coefficient of $MLIQVOL_{t-1}$ is estimated as -8.121 from equation (5.2) during the whole sample period, while in volatile market periods the coefficient is -9.33 based on the empirical results from equation (5.6), furthermore, based on equation (5.7) when the market is illiquid and volatile, the coefficient is -14.45. One can infer that the effect of $MLIQVOL_{t-1}$ on the momentum profit does depend on the market states, and the time-varying relationship between the volatility of market liquidity and the momentum profit is evidenced by our investigation.

To be more specific, the negative effect is stronger in volatile market regime, and even much stronger when the market is illiquid. The latter finding of stronger effect of $MLIQVOL_{t-1}$ on predicting momentum in illiquid market state is not surprising. Based on Barinov's (2014) argument, when the market is more illiquid, firms tend to hit high state of illiquidity in fluctuation of liquidity, because the rational investors who are lack of the ability to predict the future tendency of market are relatively reluctant to trade and the market turns out to be illiquid. In other words, the volatility of market liquidity $MLIQVOL_{t-1}$ affects momentum through $MLIQ_{t-1}$, hence, the effect of $MLIQVOL_{t-1}$ on momentum profit is enhanced in illiquid market state.

5.5.3 Momentum Crash

Daniel and Moskowitz (2014) document that the strong momentum reversal they observe from March to May in 2009 is a crash, due to the crashing up of the loser portfolios. They investigate that the momentum crash of March to May in 2009 occurred after the downward of market return, while the market volatility decreased during the crash period. In this chapter, I would like to further observe the market states before and after the momentum crash in 2009.

The data are displayed in the Table 5.5 and Figure 5.1. Be in line with Daniel and Moskowitz's (2014) work, the data suggest that, in March to May of 2009, the momentum profit jumps dramatically from 42.1 in February to -78.6% in March, when the equity market return increases significantly from a previous low, and the market return volatility turns down. In other words, the momentum crash happens after high market stress (the bear markets with high volatility), and during the revival of the contemporaneous equity market. For instance, before March 2009, the equity market return was negative, and at the beginning of crash, the market return suddenly went up to positive, from -9.94% to 8.83%. As for the volatility of market return, it declined from roughly 3% to lower than 2% since the momentum crash occurred in March 2009. On the other hand, the market turned to be more liquid during and after the crash months, in particular, from September 2008 to February 2009, the illiquidity measure varies from 0.089 to 0.094, while after March 2009, it diminishes monotonically for more than twelve months. The high market illiquidity before the momentum crash is consistent with the ACH's (2014) conclusion, which indicates that the low momentum profit is following high market illiquid. ACH (2014) also claim that the illiquidity gap between winners and losers is enlarged in illiquid market state; hence, the losers tend to be even more illiquid, meanwhile, the illiquidity effect on losers' returns exceeds the winners' price continuation effect. The extreme case of this scenario is the momentum crash, when the past losers' returns increase sharply but the winners' returns drop and the momentum profit could be significantly negative. Note that the contemporaneous market liquidity improves when the loser portfolio reverses dramatically and the crash occurs. To summarize, I observe that the momentum crash of 2009 occurs after the market stress, which is the bear market with high volatility and illiquidity; besides, the crash is during the period when the market states improve, that is, the contemporaneous equity market returns increase and volatility drops, and, more importantly, the market becomes more liquid.

In terms of the volatility of market liquidity, the observation is interesting. The $MLIQVOL_t$ is rising sharply since the beginning of 2008 until February 2009, and the data is from 0.132 to 0.296. However, from March 2009, the $MLIQVOL_t$ stays stable for a couple of months at around 0.3. The climbing of $MLIQVOL_t$ before the crash indicates that the market liquidity is getting more and more volatile, according to the definition of $MLIQVOL_t$, which is the volatility of monthly market liquidity from t-36 to t-1. In addition, the stability of high $MLIQVOL_t$ implies the prior 36-month market liquidity fluctuates violently but the extent of fluctuation is not changing dramatically. The stability of $MLIQVOL_t$ may not be able to reflect the amelioration of market stress, and it is not contradiction, because $MLIQVOL_t$ catches the fluctuation of $MLIQ_t$, which could be increasing or decreasing.

One may say that the strong reversal of momentum profit during the crash period is a compelling evidence to support our empirical result of negative association between momentum profits and $MLIQVOL_t$, that is, the momentum payoff reduces when the volatility of market illiquidity increases. However, there might be an alternative explanation, considering the source of the negative relationship, between the asset returns and the volatility of liquidity, is from winner portfolios, according to the empirical results of Penal B of Table 5.2, but, the direct reason of the momentum crash in 2009 is the loser portfolio's quicker and stronger reversal than the winner groups.

Finally, one could consider the drying of market liquidity (low market liquidity level) and high volatile of market liquidity level (increasing volatility of market liquidity) as the market stress, which could be potentially taken as the sign for the impending momentum crash, along with the up market returns after downwards. However, although the volatility of market illiquidity increased sharply in a couple of months before the momentum crash at the beginning of 2009, I am not able to take event study to prove our hypnosis, by the accessible dataset.

As aforementioned, the source of the momentum crash is a result of investors' behavior, and could be possibly explained by the lack of overconfidence, as well as the time-varying of market beta and firms' liquidity. However, with the predicting signals of momentum crash, investors could continue to make profits by reversing the traditional strategy. That is, the strategy of buying past losers and selling past winners before the crash occurs could generate significant positive payoff, as long as the prediction of the oncoming crash is accurate.

5.5.4 Limitation

This chapter provides a few implications for practitioners and future research; however, there exists limitations according to methodology restrictions. The limitations consist of two folds. First, in this chapter, only one liquidity measure, the ratio of Return to dollar volume, is adopted. As discussed in previous chapters, six liquidity measures from three dimensions are studied, and those various proxies capture different aspects of liquidity, with all being evidenced to affect asset returns. Regarding the volatility of liquidity measured by R/Dvol, it is also examined in chapter 4 that the volatility price impact proxy is negatively related to asset returns in cross-sectional dimension, nevertheless, the extent of liquidity volatility to impact on stock returns partially depends on the measurement adopted. Therefore, the restriction of liquidity measure could potentially be one of limitation. Second, only one moment crash event is studied in this chapter due to short of data. Since there is only one moment crash occurs during 1961-2011, it is not feasible to compare the moment crash in 2008 with crash events in terms of the changes of market state variables, thus, the prediction of moment crash event by observing the market state variables is not highly reliable and practical. Hence, before further study is conducted, it is not suggested to follow the prediction conclusion for investment strategy.

5.6 Conclusion

This study is motivated by Pereira and Zhang (2010) and ACH's work, which investigate the negative relationship between the volatility of market liquidity and the asset return, and the negative impact of market-wide illiquidity on the momentum profit. However, a recent study by Chordia, Subrahmanyam, and Tong (2014) claims that the momentum anomaly is supposed to be reduced in liquid market state due to increased arbitrage activities.

I am interested in the momentum portfolios return after the volatile market liquidity fluctuation, providing the significant relationship between the volatility of market liquidity and asset expected returns. In this chapter, the empirical results from the time-series and cross-sectional regressions convince that the high volatility of market liquidity leads to the reduction of momentum effect, otherwise, when the market liquidity stays stable, the price continuation is stronger and hence the momentum payoff increase. This conclusion applies to the momentum both in portfolio and individual stock level.

The negative association between the volatility of market liquidity and the momentum payoff is not constant but time-varying and state-dependent. I introduce two dummy variables, which represent the market regimes regarding market liquidity and volatility, into time-series regressions. The negative effect is stronger in volatile market state, and even much stronger when the market is illiquid.

The volatility of market liquidity is also linked to the event of momentum crash. The momentum crash is due to the quicker and stronger reversal of loser portfolios than winner portfolios. Daniel and Moskowitz (2014) find the crash occurs after the market stress and during a revival of market. In particular, the equity market is bear before the crash, and contemporaneous market returns rebound during the crash period. I have more interesting findings regarding the volatility of market liquidity. Specifically, the volatility of market liquidity climbs twice before the momentum crash, and stay relatively stable during and after the crash. The pattern of volatility of market liquidity could be viewed as the sign for the impending momentum crash, along with the up market return after downwards. The investor could possibly generate significant profit in a momentum crash event by reversing the traditional strategy.

Table 5.1: Descriptive statistics of firm fundamentals and market states variables

This table demonstrates the statistics of monthly variables. The listed variables are observed or calculated from a sample of average 2657 NYSE-AMEX firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. In Panel A, the mean, median, standard deviations are obtained by the time-series average of monthly cross-sectional mean, median, standard deviation. CAP is the market capitalizations of firms. RET is the monthly return of assets. PRICE denotes the closing prices at the end of month. DVOL is firms' monthly dollar volume, and calculated by multiplication of CAP and PRICE. In Panel B, the time-series mean, median and standard deviation of the regression variables are reported. MOM is the return of momentum portfolios, which is the difference between winner's and loser's return, and the winner/loser portfolios are constructed by sorting stocked into 10 deciles from month t-12 to t-2. MVOL is the market volatility, the standard deviation of daily value-weighted CRSP market index returns over the month. DOWN is the dummy variable indicating the market trend, taking the value of one if the prior 24 months cumulative returns of the value-weighted market portfolio is negative or zero if the cumulative returns is non-negative. MLIQ is obtained by equal-weighted average individual assets' illiquidity, which is proxied by Amihud(2002) measure (return to dollar volume). MVOLLIQ is the volatility of market illiquidity,by constructing the volatility by the coefficients of variation of monthly liquidity - the standard deviation of prior 36 monthly liquidity levels divided by the mean of prior 36 monthly liquidity levels. The three Fama-French pricing factors, RM are the return of market portfolio excess to the risk-free rate, HML (High Minus Low) is the average return on the two value portfolios minus the average return on the two growth portfolios, SMB (Small Minus Big) is the average return on the three small portfolios minus the average return on the three big portfolios. The Penal C displays the correlation matrix among the variables in Penal B.

		Mean	**Median**	**Standard deviation**
Panel A	**CAP**	1.370	0.315	3.616
	RET	0.087	0.078	0.223
	PRICE	29.519	22.667	22.188
	DVOL	41.533	9.149	30.155
Panel B	**MOM**	1.368	1.845	6.972
	MVOL	0.008	0.007	0.005
	DOWN	0.156	NAN	0.363
	MLIQ	0.248	0.201	0.180
	MVOLLIQ	0.188	0.162	0.067
	RM	0.438	0.775	4.531
	HML	0.339	0.365	3.240
	SMB	0.251	0.095	3.001

Penal C		**MOM**	**MLIQ**	**MVOLLIQ**	**MVOL**	**DOWN**	**RM**	**HML**
	MLIQ	0.031						
	MVOLLIQ	-0.078	0.307					
	MVOL	-0.080	-0.135	0.036				
	DOWN	-0.108	0.136	0.261	0.409			
	RM	-0.163	-0.098	0.002	-0.306	-0.087		
	HML	-0.444	0.066	0.022	0.025	0.060	-0.183	
	SMB	-0.113	-0.055	-0.027	-0.200	0.065	0.331	-0.145

Table 5.2 Regression analysis of the momentum payoff and market states

This table reports the time-series regression results of euqation(1), using the elegeble NYSE-AMEX common listed firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. In regression of equation (5.2), the set of explanory variables are the market states variables, volatility of market liquidity (MVOLLIQ), market liquidity (MLIQ), market indicator (DOWN), market return volatility (MVOL), and Fama-French pricing factors (RM, HML, and SMB). The dependent variables are momentum returns, winner portfolio returns and loser portfolio returns, and the three sets of regression results are displayed in Panel A, B and C, respectively. Each panel contains the estimated coefficeints and the t-statistics of the explanory variables. From Model 1 to Model 6, numerous variables are included in the regressions. We use * to denote the significance of the coefficients at 5%.

		MOM											
		Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
		coefficent	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**
Panel A													
	INTERCEPT	3.260 *	4.263	3.115 *	4.069	5.360 *	6.136	5.322 *	5.779	4.022 *	7.604	4.998 *	5.221
	MVOLLIQ	-7.038 *	-1.833	-4.954	-1.254	-6.886 *	-1.827	-6.749 *	-1.772			-8.121 *	-1.995
	MLIQ											1.936	1.233
	DOWN			-1.550 *	-2.120			-0.103	-0.129	-0.476	-0.617	-0.266	-0.328
	MVOL					-238.859 *	-4.703	-235.702 *	-4.179	-225.051 *	-4.008	-218.312 *	-3.757
	RM	-0.336 *	-5.561	-0.351 *	-5.785	-0.411 *	-6.699	-0.411 *	-6.693	-0.414 *	-6.721	-0.406 *	-6.585
	HML	-1.076 *	-13.537	-1.068 *	-13.453	-1.092 *	-13.982	-1.092 *	-13.918	-1.092 *	-13.893	-1.094 *	-13.948
	SMB	-0.270 *	-3.011	-0.248 *	-2.760	-0.316	-3.577	-0.314 *	-3.494	-0.304 *	-3.378	-0.312 *	-3.474

		WINNER											
		Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
		coefficent	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**
Panel B													
	INTERCEPT	1.713 *	4.792	1.649 *	4.607	2.512 *	6.112	2.458 *	5.672	1.862 *	7.483	2.122 *	4.736
	MVOLLIQ	-3.349 *	-1.866	-2.435	-1.318	-3.291 *	-1.856	-3.092 *	-1.678	*		-4.514 *	-2.370
	MLIQ											2.006 *	2.730
	DOWN			-0.680 *	-1.988			-0.150	-0.399	-0.321	-0.884	-0.318	-0.840
	MVOL					-90.900 *	-3.803	-86.319 *	-3.253	-81.439 *	-3.083	-68.303 *	-2.512
	RM	1.045 *	37.023	1.038 *	36.647	1.016 *	35.164	1.016 *	35.138	1.015 *	35.053	1.022 *	35.447
	HML	-0.466 *	-12.545	-0.463 *	-12.460	-0.472 *	-12.849	-0.471 *	-12.769	-0.471 *	-12.748	-0.473 *	-12.899
	SMB	0.342 *	8.176	0.352 *	8.370	0.324 *	7.793	0.327 *	7.735	0.332 *	7.856	0.329 *	7.825

Table 5.2 Regression analysis of the momentum payoff and market states

This table reports the time-series regression results of euqation(1), using the elegeble NYSE-AMEX common listed firms from Jan., 1962 to Dec., 2011 recorded in CRSP tape. In regression of equation (5.2), the set of explanory variables are the market states variables, volatility of market liquidity (MVOLLIQ), market liquidity (MLIQ), market indicator (DOWN), market return volatility (MVOL), and Fama-French pricing factors (RM, HML, and SMB). The dependent variables are momentum returns, winner portfolio returns and loser portfolio returns, and the three sets of regression results are displayed in Panel A, B and C, respectively. Each panel contains the estimated coefficeints and the t-statistics of the explanory variables. From Model 1 to Model 6, numerous variables are included in the regressions. We use * to denote the significance of the coefficients at 5%.

		LOSER											
		Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
		coefficent	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**	**coefficent**	**t-statistics**
Panel C													
	INTERCEPT	-1.547 *	-2.901	-1.465 *	-2.741	-2.848 *	-4.656	-2.864 *	-4.442	-2.160 *	-5.838	-2.876 *	-4.284
	MVOLLIQ	3.689	1.378	2.519	0.913	3.595	1.362	3.656	1.333			3.607	1.264
	MLIQ											0.070	0.063
	DOWN			0.870 *	1.741			-0.047	-0.083	0.155	0.288	-0.052	-0.092
	MVOL					147.960 *	4.160	149.383 *	3.782	143.613 *	3.656	150.009 *	3.681
	RM	1.381 *	32.790	1.389 *	32.825	1.427 *	33.195	1.427 *	33.165	1.429 *	33.180	1.428 *	33.047
	HML	0.610 *	11.003	0.605 *	10.920	0.620 *	11.333	0.620 *	11.295	0.620 *	11.287	0.620 *	11.281
	SMB	0.612 *	9.798	0.600 *	9.557	0.641 *	10.344	0.642 *	10.186	0.636 *	10.111	0.642 *	10.177

Table 5.3 Individual stock momentum and market states

The Panel A displays the monthly cross-sectional regressions results of equation (5.3), which is the individual assets return in month t regressed on the the past cumulative return (R(t-12:t-2)), the past cumulative negative return (R(t-12:t-2)-) and the firm level volatility of liquidity (LIQVOL). The coefficient of the past cumulative return presents the firm level momentum effect, while the one of the past cumulative negative return measures the additional marginal momentum effect from the previous downwards. The cross-sectional regressions are conducted monthly. The coefficients reported in the table are obtained by the time-series mean of monthly estimation results. The t-statistics are calculated by the time-series coefficients estimation.The Panel B is the time-series regressions results. The obtained cross-sectional momentum effect coefficients, beta 1 and beta 2, are, respectively, regressed against the market state variables, volatility of market liquidity (MVOLLIQ), market illiquidity (MVOL), market indicator (DOWN) , and market volatility (MVOL).

		Regression on returns			
		Model 1		Model 2	
		coefficient	**t-statistics**	**coefficient**	**t-statistics**
Panel A					
	INTERCEPT	1.7834 *	2.4377	2.4391 *	3.9868
	R(t-12:t-2)	0.0104 *	2.1905	0.0130 *	2.9024
	R(t-12:t-2)-			0.0182 *	3.2933
	LIQVOL	-0.0013 *	-3.9032	-0.0019 *	-2.9183

		Regression on beta1		**Regression on beta2**	
		coefficent	**t-statistics**	**coefficent**	**t-statistics**
Panel B					
	INTERCEPT	2.6846 *	3.5085	3.3773 *	2.9922
	MVOLLIQ	-1.4587 *	-2.9644	-2.9645 *	-3.4213
	MLIQ	-0.9563	-1.2234	-0.7241	-0.9655
	DOWN	-0.5963	-0.8932	-0.3902	-0.1875
	MVOL	-1.8735 *	-1.9294	-2.3377 *	-1.9084

Table 5.4: Time-varying effect analysis

This table reports the time-series regression results of euqation (5.6) and (5.7). The dummy variables Ivol and Iliq indicates the states of the market volatility and the market liquidity, respectiely. The former indicator equals one if the market volatility is high and zero otherwise, while the latter instrument equals one if the market liquidity is in low state and zero otherwise. Thus, both are the sequences of one and zero; in particular, 30% of Ivol and and 50% of Iliq are ones. The first colume is the explanory variables and the second colume is the corresponding coefficients. Rest of the four columes are the estimated coefficients and the t-statistics. We use * to denote the significance of the coefficients at 5%.

		euqation (5.6)		euqation (5.7)	
variable	**coefficent**	**estimation**	**t-statistics**	**estimation**	**t-statistics**
1	alpha	4.057 *	7.153	2.325 *	2.322
I_{vol}	alpha'	0.925 *	3.410	0.133 *	1.982
I_{vol}*I_{liq}	alpha''			0.244 *	3.509
MLIQVOL	beta1	-4.992	-1.363	0.129	0.028
I_{vol}*MLIQVOL	beta1'	-9.330 *	-3.904	-6.210 *	-1.998
I_{vol}*I_{liq}*MLIQVOL	beta1''			-8.246 *	-4.234
MLIQ	beta2	1.820	1.099	0.997 *	1.766
DOWN	beta3	-0.198	-0.090	-0.098 *	1.884
MVOL	beta4	-299.992 *	-9.218	-190.215 *	-2.435
RM	beta5	-0.592 *	-2.129	-0.490	-3.217
HML	beta6	-0.908 *	-2.904	-1.025	-2.933
SMB	beta7	-0.190 *	-1.998	-0.272	-2.009

Table 5.5 Data of market states from 2008 to 2011

MOM is the return of momentum portfolios, which is the difference between winner's and loser's return, and the winner/loser portfolios are constructed by sorting stocked into 10 deciles from month t-12 to t-2. RM is the market portfolio retusn excess to the risk-free rate. MVOL is the market volatility, the standard deviation of daily value-weighted CRSP market index returns over the month. MLIQ is obtained by equal-weighted average individual assets' illiquidity, which is proxied by Amihud(2002) measure (return to dollar volume). MVOLLIQ is the volatility of market illiquidity,by constructing the volatility by the coefficients of variation of monthly liquidity - the standard deviation of prior 36 monthly liquidity levels divided by the mean of prior 36 monthly liquidity levels.

month	MOM	RM	MVOL	MLIQ	MVOLLIQ
200801	-0.165	-0.0633	0.0148	0.0477	0.1322
200802	0.180	-0.0316	0.0128	0.0466	0.1333
200803	0.096	-0.0091	0.0181	0.0462	0.1327
200804	0.022	0.0464	0.0112	0.0539	0.1327
200805	0.044	0.0188	0.0120	0.0425	0.1370
200806	0.212	-0.0838	0.0142	0.0484	0.1364
200807	-0.099	-0.0072	0.0127	0.0522	0.1376
200808	0.037	0.0153	0.0329	0.0627	0.1414
200809	0.089	-0.0957	0.0492	0.0937	0.1411
200810	0.101	-0.1715	0.0439	0.0837	0.1582
200811	0.233	-0.0777	0.0310	0.0736	0.2393
200812	-0.065	0.0184	0.0246	0.0739	0.2736
200901	-0.075	-0.0793	0.0220	0.0687	0.2865
200902	0.421	-0.0994	0.0308	0.0829	0.2960
200903	-0.786	0.0883	0.0193	0.0643	0.2988
200904	-0.918	0.1017	0.0182	0.0585	0.3149
200905	-0.381	0.0533	0.0131	0.0570	0.3123
200906	0.183	0.0044	0.0129	0.0533	0.3107
200907	-0.131	0.0776	0.0106	0.0426	0.3102
200908	-0.496	0.0323	0.0097	0.0418	0.3082
200909	-0.075	0.0415	0.0138	0.0412	0.3107
200910	0.042	-0.0249	0.0101	0.0442	0.3098
200911	0.025	0.0564	0.0067	0.0415	0.3097
200912	0.071	0.0280	0.0102	0.0337	0.3061
201001	-0.087	-0.0351	0.0113	0.0346	0.3033
201002	0.080	0.0339	0.0052	0.0340	0.3053
201003	0.030	0.0630	0.0095	0.0325	0.3037
201004	0.065	0.0212	0.0208	0.0376	0.3032
201005	0.026	-0.0786	0.0166	0.0425	0.3006
201006	-0.040	-0.0567	0.0131	0.0432	0.2996
201007	0.038	0.0727	0.0116	0.0400	0.2968
201008	-0.063	-0.0481	0.0103	0.0402	0.2959
201009	0.029	0.0956	0.0074	0.0378	0.3000
201010	0.042	0.0402	0.0095	0.0388	0.2998
201011	0.069	0.0063	0.0055	0.0323	0.3025
201012	-0.082	0.0676	0.0071	0.0311	0.3064
201101	-0.042	0.0205	0.0081	0.0297	0.3112
201102	0.028	0.0349	0.0103	0.0362	0.3205
201103	0.084	0.0057	0.0059	0.0289	0.3305
201104	0.036	0.0295	0.0073	0.0327	0.3352
201105	0.012	-0.0128	0.0107	0.0355	0.3466
201106	0.003	-0.0168	0.0102	0.0316	0.3523
201107	0.037	-0.0230	0.0307	0.0503	0.3577
201108	0.076	-0.0595	0.0188	0.0503	0.3662
201109	-0.041	-0.0753	0.0197	0.0496	0.3658
201110	-0.004	0.1134	0.0201	0.0486	0.3645
201111	0.053	-0.0029	0.0124	0.0359	0.3313

Figure 5.1: momentum payoffs and market portfolio returns from 2008 to 2011.

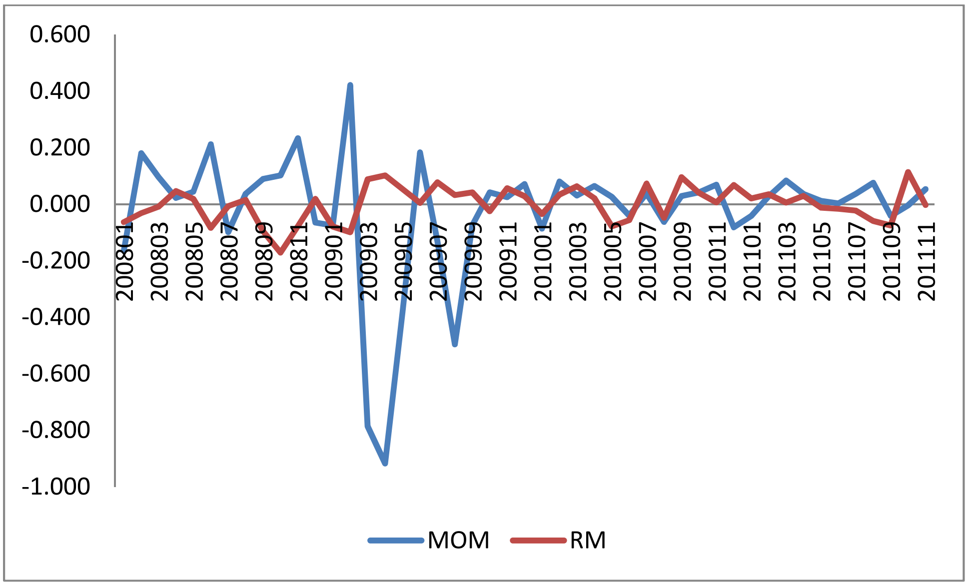


Figure 5.2: momentum payoffs and market aggregated illiquidity (different scale) from 2008 to 2011.

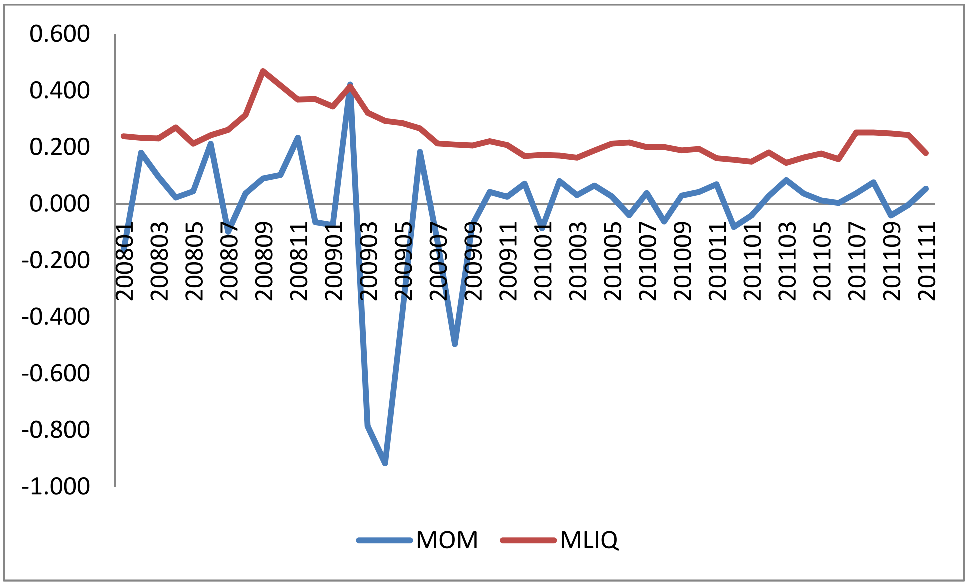


Figure 5.3: momentum payoffs and volatility of market aggregated illiquidity from 2008 to 2011.

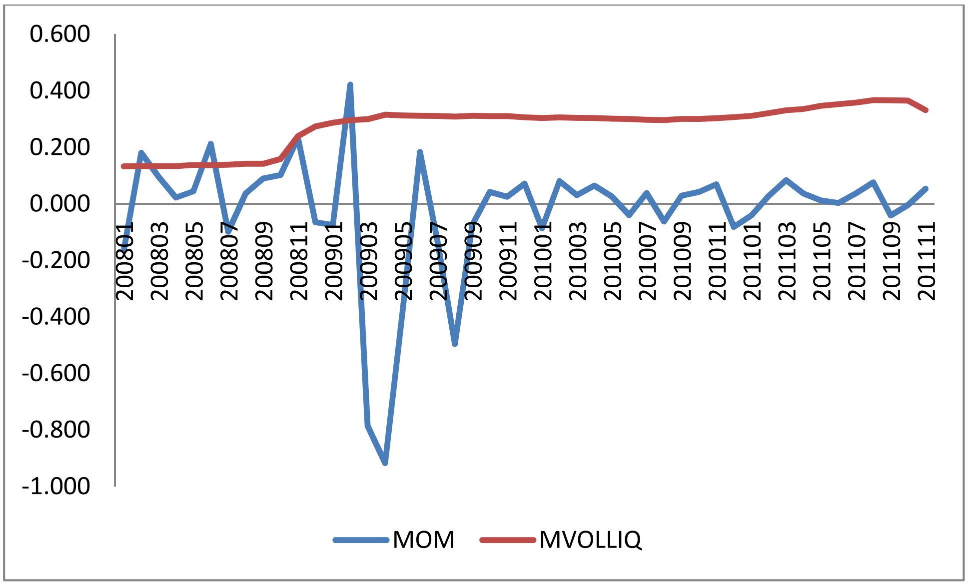
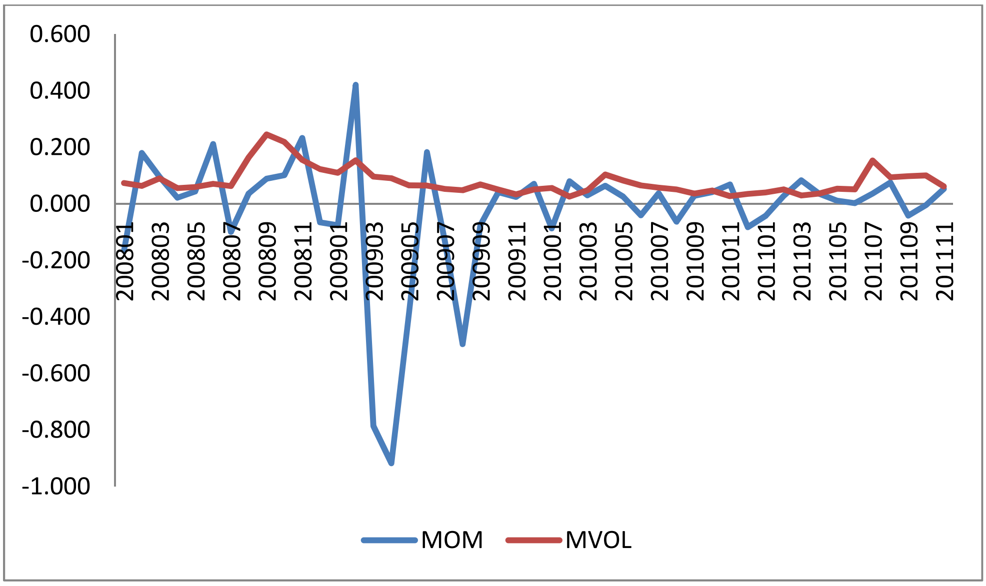


Figure 5.4: momentum payoffs and volatility of market returns (different scale) from 2008 to 2011.



Chapter 6

Conclusions

This thesis investigates the performance of the liquidity measures in the equity market, the volatility of liquidity regarding the pricing issues, and the impact of volatility of market liquidity on momentum profit. Liquidity is an important feature of financial markets, indicating the easiness of an asset could be traded, i.e. even at a low cost with high speed and little impact on prices. The source of liquidity contains exogenous transaction costs, inventory risk and private information. During the last decades, the investigation of liquidity has attracted the interest of many researchers and practitioners. The importance of liquidity on the fundamental essence is exemplified by the impact on asset returns and trading strategies. In this context, this thesis investigates the most important liquidity components in order to conduct a comparative analysis on the liquidity risk premia of securities. It then conducts a causality analysis that focuses on the interrelationship between the liquidity components and the market dynamics. Moreover, it compares the volatility of liquidity risk through an asset pricing framework considering several dimensions of liquidity, including transaction costs, trading activity and price impact. Finally, it studies the prediction of the volatility of market liquidity on momentum payoff, especially its performance during a momentum crash period.

Liquidity has wide-range effects on financial markets, of which the most fundamental one is on asset returns. A rational investor would prefer an asset which is liquid and easy to trade in market, unless a satisfactory compensation is paid for bearing the illiquidity of the holding asset. Here the difficulty of trading might be costly and it should be taken in to account. Moreover, the liquidity risk, which is defined as the sensitivity of the liquidity of individual asset to the market liquidity, also affects the asset expected returns. The asset with higher sensitivity usually requires higher returns. Besides, a rational investor would always prefer to trade on a liquid state, and there are pervasive evidences correlating heavier trading volumes and higher market liquidity. Thus, the state of liquidity could be adopted by investors, and liquidity is important for investor to design their investment strategies.

Liquidity has been intensively studied in literature, including the market microstructure, the origins of illiquidity through trading mechanism, and the effect of liquidity on asset returns. Those studies on liquidity effect on asset returns are carried out by examining the cross-sectional difference in liquidity and returns, or by testing the effect of changes in liquidity over time. In the cross-sectional dimension, both the liquidity level and the second moment of liquidity are determined to be related to the cross-sectional returns. Furthermore, since the process of liquidity is time-varying, the fluctuation of market aggregated or individual asset liquidity may propagate to the asset returns. These theoretical and empirical studies also suggest that liquidity can help in explaining a few puzzles, including the equity premium puzzle, the risk-free rate puzzle and the small firm effect. Though there is no precise definition for liquidity and it is hard to measure, the empirical studies of liquidity have to rely on the quantification, i.e., the measurement of liquidity, and without a definitive quantitative definition, one could not expect to measure the liquidity directly. Even after extensive studies on the measurement of liquidity, a unanimous agreement remains elusive on how to accurately measure liquidity, especially in terms of the effect of individual asset liquidity on its return.

This thesis contributes to the literature in several ways. First, this thesis studies these liquidity measures in a comparative framework. It is suggested that the significance of liquidity is time-specific and the heterogeneity between liquidity components exhibits a strong Business Cycle effect. Second, my analyses consider the liquidity components involving the market dynamics, and the interrelationship between them helps us in understanding the performance of the liquidity measures. Third, it contributes to the literature on the volatility of liquidity. The empirical results are consistent with the literature and additionally provide evidence of heterogeneity across various liquidity components and volatility specifications. Fourth, this thesis contributes to literature by investigating that the individual volatility of liquidity commoves across assets, and examining the pricing of systematic component of the volatility of liquidity on asset returns. Finally, it contributes to the momentum study by investigating the association between the momentum profit and the volatility of market liquidity.

Chapter 3 conducts a comparative analysis of six liquidity measures regarding the risk-return trade-off, using data from CRSP over the period from 1962 to 2011. The liquidity measures employed are spread / relative spread, dollar volume / turnover ratio, and return to dollar volume / return to turnover ratio - they represent the three constituents of liquidity, i.e., transaction cost, trading activity and price impact, respectively. The analysis is carried out through cross-sectional and time-series approaches. The former part in the cross-sectional dimension employs the conventional Fama-MacBeth approach controlling several factors on firm fundamentals at the individual stock level, while in the study in the time-series dimension by the latter method, the interaction of liquidity constituents (or dimensions) and market information indicators is studied at the market-wide level. The market macroeconomics conditions differ in each Business Cycle, thereby having the potential in influencing the performance of various liquidity measures. Therefore, the Business Cycles are considered in the cross-sectional tests, with the intention of detecting the time varying performance of the liquidity measures. In addition, the comparative analysis of the liquidity risk premia is followed by a time-series analysis that aims to investigate the potential bidirectional relationships between liquidity and market characteristics. In the time-series analysis, a vector autoregression (VAR) representation, of market-wide liquidity measures and market characteristics, is employed in order to investigate the potential causality effects between the liquidity components and the market dynamics. The causality effects are investigated using daily frequency time-series data. In particular, the market-wide liquidity components are signified by transaction cost, trading activity and price impact, while the market directions, the market volatility and the momentum proxies stand for the market variables of conditions.

The empirical findings of Chapter 3 are consistent with the foundations of liquidity measures though several structural changes have taken place during the examined time period. On the one hand, there is evidence in favor of a significant presence of heterogeneity between the liquidity constituents varies through time. The estimations of slopes of the liquidity measures are significant in the whole sample horizon, but only in certain Business Cycles in the sub-periods. It is also observed that the liquidity risk premium escalates during downturns of the market conditions. In particular, the association between the asset liquidity and return in the cross-sectional dimension is relatively stronger in the period of lower market liquidity. Moreover, there is evidence that the trading activity component of liquidity dominates conventional risk factors such as the size effect. Similar results are obtained with the return to dollar volume which dominates the size and the momentum effects. On the other hand, the results of Granger causality indicate that bidirectional causality exists within the same category of liquidity measures, and between transaction cost and price impact measures, while the price impact measures are Granger caused by transaction costs and trading activity. It is also found that the market-wide characteristics (volatility and direction variables) Granger cause the trading activity and the price impact liquidity components, which in turn Granger cause the past performance of asset returns. The bidirectional causality exists between the market-wide characteristics, (i.e. volatility and direction variables) and one of price impact and trading activity measures. These return-related indicators, however, do not cause transaction cost proxies. Moreover, the Granger causality by all of the three momentum proxies to the turnover ratio is significant.

Chapter 4 provides a comparative analysis of the volatility of liquidity risk through an asset pricing framework considering several dimensions of liquidity such as transaction cost, trading activity and price impact. This chapter focuses on the informational content of the volatility of the liquidity measure, through the examination of several research hypotheses, including whether the volatility liquidity is priced in a conventional Fama-MacBeth framework, as well as whether a commonality of the volatility of liquidity across assets exists and is priced on asset returns.

The Fama-MacBeth approach is employed in order to run cross-sectional regressions of individual monthly stocks return against its share characteristics including liquidity level and liquidity volatility in APT equations. Two volatility specifications, Vol1 and Vol2, are considered in the regressions, respectively. Vol1 is able to capture the variation of daily liquidity within month. The other employed proxy, Vol2, which reflects the fluctuation of liquidity of prior 36 months, has been widely used in literature. Based on the hypothesis that a set of common and idiosyncratic variables underline the liquidity volatility, the principal component analysis (PCA) is conducted to extract the commonality of the volatility of liquidity across all assets. In addition to estimating common factors of volatility of liquidity for each measure individually, I also stack the volatility of liquidity of six (or four) measures into one matrix and then form the variance-covariance matrix Ω

and extract the corresponding eigenvectors as the common factors across all of the six (or four) liquidity measures. Finally, I construct a mimicking portfolio to track the systematic risk of volatility of liquidity, with respect to Vol1 and Vol2. On examining the pricing of the volatility of liquidity, I ran the multivariable time-series regressions, and construct a mimicking factor that enables us to track how the fluctuation of the volatility of liquidity is reflected on asset returns.

The empirical results of Chapter 4 are on volatility of liquidity and its commonality. First, the volatility of liquidity is negatively associated with the cross-sectional asset returns. The complementary contribution to the literature is the convincing evidences that the negative association is robust to the liquidity measures. In addition, different results are obtained from two volatility specifications, that is, Vol1 is negatively associated with asset return when the liquidity is measured in the aspect of transaction cost, while Vol2 holds the significant and negative relationship with asset return in the dimensions of trading activity and price impact of liquidity. Second, commonality of volatility of liquidity exists based on the PCA results, and the commonality is significantly priced in asset returns. Furthermore, in addition to the systematic risk of volatility of liquidity across individual assets, I use an alternation of volatility of market-wide liquidity to examine the pricing of systematic risk of volatility of liquidity.

Chapter 5 investigates the relationship between the momentum payoff and the volatility of market liquidity. Specifically, the analysis is undertaken in both time-series and cross-sectional dimensions, respectively, on momentum profits and momentum effect coefficients of the regressions of the volatility of market liquidity. In the regressions, I consider some other market states, including market returns, market volatility, market liquidity and market dummy variables. Furthermore, the dummy variables is introduced as instrumental indicator of high or low market volatility and liquidity into the time-series regressions, in order to examine whether the association between the momentum profit and the volatility of market liquidity is state-dependent. Finally, I put the momentum crash in 2009 under a close inspection, which reveals the changes of market liquidity and its volatility before the crash occurred.

The finding of Chapter 5 contains three parts. The momentum profits decrease following high volatility of market liquidity and increase when the market liquidity is stable. This relationship is state-dependent; in particular, it is stronger when the market is in the state of volatile and illiquid. The volatility of market liquidity increases sharply a couple of months before the momentum crash, and it implies that the volatility of liquidity could be recognised as the indicators of market stress to induce the momentum crash.

Overall my empirical findings have some implications for practitioners. Since the liquidity level and the volatility of liquidity are related to the required asset returns in the cross-section dimension, an investor should consider this fact when he buys or holds an assets/portfolio. In practice, the liquidity measures are employed for assessing the liquidity; however, according to this study, the various liquidity measures perform differently and the heterogeneity exists between the measures over time, and the macroeconomics factors also matter. Therefore, an investor should consider an appropriate measure in order to quantify his expectation. Another consequence is on zero-cost trading strategies, which, in principle, make profit. Actually, it is common sense that illiquid assets generate higher returns, while lower returns are normally from liquid assets. However, the second moment of liquidity could provide more solid and consistent results according to the negative relationship with asset returns, over time and across measures. Thus, it is more efficient to consider the volatility of liquidity in order to make profit from a zero-cost trading strategy, which is buying the assets with low volatility of liquidity and selling the assets with high volatility of liquidity. The last implication is on the momentum crash. The momentum profit is related to the market liquidity and its volatility, even in the adverse situation, the momentum crash could possibly be predictable by the changes of market stress, including the market liquidity and its volatility. Note that the momentum crash indicates that the loser portfolios have higher expected returns than the winner portfolios instead. Thus, at this stage, reversing the traditional momentum strategy could possibly make positive profits.

The research can be further extended in number of ways. First, one could investigate the impact of market conditions on the performance of liquidity measures in each Business Cycle; a more robust measure, which could consider the market conditions or weight by the individual measures, might also be derived. Second, the pricing of the volatility of liquidity could be examined in the GMM framework. More affecting factors, for instance, the Business Cycles, could also be considered in the investigation. Third, the arbitrage of momentum strategy deserves further investigation. In particular, the different liquidity or volatility of liquidity of assets could be exploited, for instance, to group the assets with differential liquidity, volatility of liquidity and past returns, and obtain the possibility to make profit by the trading strategy according to these characteristics. Finally, one could also focus on the arbitrage based on momentum strategy by concentrating the market states. Specifically, the oncoming momentum payoff is affected by the change of market states, thus, adjusting the momentum strategies according to the market states could potentially maximize the profit.

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